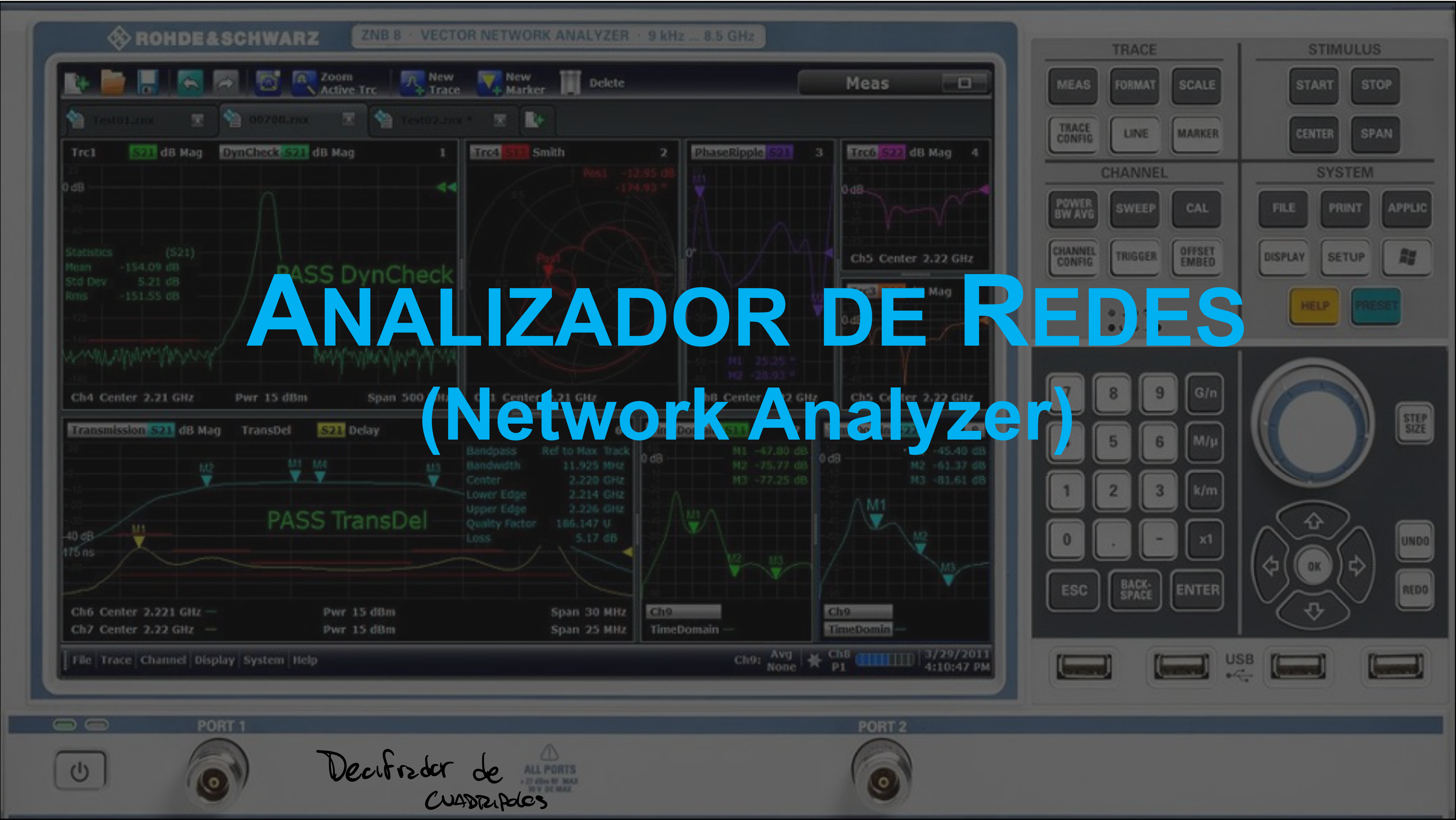
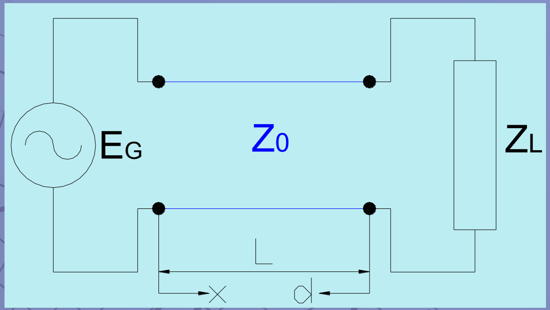
ANALIZADOR DE REDES
(Network Analyzer)



Decifrador de
CUADRIPOLOS

Conocimientos Previos

Líneas de Transmisión



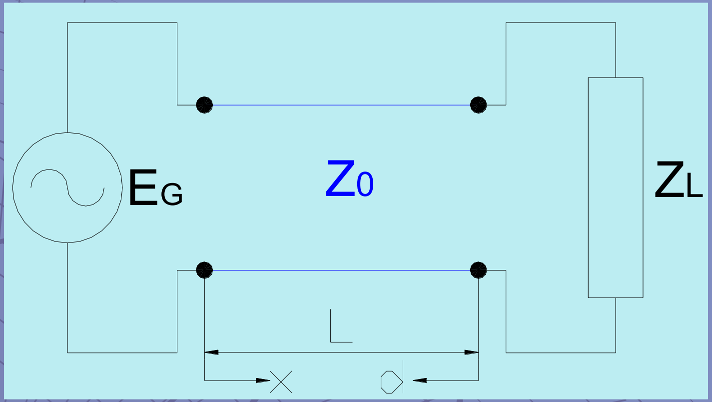
$$E_{(d)} \cdot e^{j\cdot\omega\cdot t} = \frac{E_L + I_L \cdot Z_0}{2} \cdot e^{\alpha\cdot d} \cdot e^{j\cdot(\omega\cdot t+\beta\cdot d)} + \frac{E_L - I_L \cdot Z_0}{2} \cdot e^{-\alpha\cdot d} \cdot e^{j\cdot(\omega\cdot t-\beta\cdot d)}$$

$$I_{(d)} \quad e^{j \quad t} \quad \frac{E_L \quad I_L \quad Z_0}{2 \quad Z_0} \quad e^{\quad d} \quad e^{j \quad t \quad d} \quad \frac{E_L \quad I_L \quad Z_0}{2 \quad Z_0} \quad e^{\quad d} \quad e^{j \quad t \quad d}$$

El primer término representa una señal que viaja desde el generador hacia la carga ya que para que sea constante al aumentar *t* (avance en el tiempo), *d* (distancia desde la carga) debe disminuir. Análogamente el segundo termino una señal que viaja de la carga al generador

Conocimientos Previos

Líneas de Transmisión

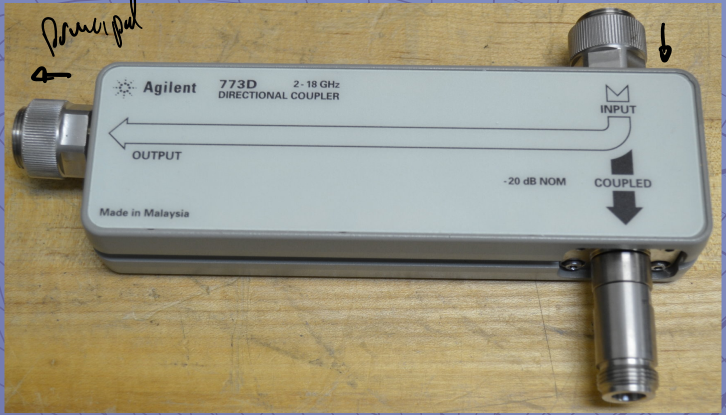


La relación entre señal reflejada e incidente se denomina coeficiente de reflexión (Γ), cumpliéndose las siguientes relaciones:

$$\Gamma = \frac{e_r}{e_i} \qquad \Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} \qquad ROE = \frac{1 + |\Gamma|}{1 - |\Gamma|} \qquad R.L. = -20\log|\Gamma|$$

Conocimientos Previos

Acopladores direccionales



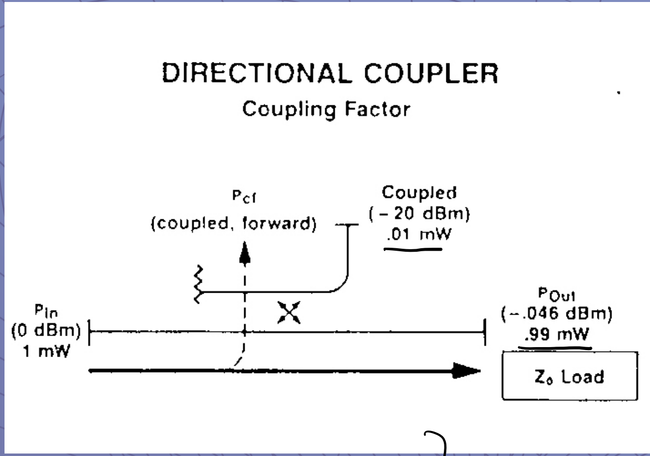
a un proporcional
b a la reflejada
de la salida

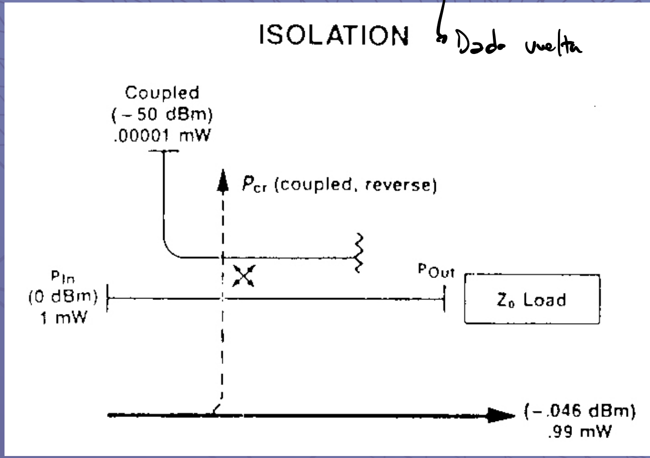
		Keysight 772D	Keysight 773D
Description		Dual directional coupler	Directional coupler
Frequency range		2 to 18 GHz	2 to 18 GHz) !
Minimum directivity Lo más adelante		39 dB (0.1 – 2 GHz) typical 30 dB (2 – 12.4 GHz) 27 dB (12.4 – 18 GHz) 20 dB (18 – 20 GHz) typical	39 dB (0.1 – 2 GHz) typical 30 dB (2 – 12.4 GHz) 27 dB (12.4 – 18 GHz) 21 dB (18 – 20 GHz) typical
Maximum main line SWR → Γ		1.05 (0.1 – 2 GHz) typical 1.28 (2 – 12.4 GHz) 1.40 (12.4 – 18 GHz) 1.29 (18 – 20 GHz) typical	1.04 (0.1 – 2 GHz) typical 1.21 (2 – 12.4 GHz) 1.27 (12.4 – 18 GHz) 1.16 (18 – 20 GHz) typicalw
Maximum coupled line SWR		1.08 (0.1 – 2 GHz) typical 1.30 (2 – 12.4 GHz) 1.40 (12.4 – 18 GHz) 1.17 (18 – 20 GHz) typical	1.07 (0.1 – 2 GHz) typical 1.30 (2 – 12.4 GHz) 1.40 (12.4 – 18 GHz) 1.17 (18 – 20 GHz) typical
Nominal coupling (dB)[4]		20 ± 1 dB (2 – 18 GHz)	20 ± 1 dB (2 – 18 GHz)
Max. coupling variation with Freq. [4]		<±1.0 dB or 2 dB peak-to-peak (2 – 18 GHz)	<±1.0 dB or 2 dB peak-to-peak (2 – 18 GHz)
Tracking between auxiliary arms		<±0.7 dB[1,2]	N/A[2]
Maximum main line residual loss		<0.26 dB (0.1 – 2GHz) typical <1.5 dB (2 – 18 GHz)	< 0.15 dB (0.1 – 2 GHz) typical <0.9 dB (2 – 18 GHz) <0.9 dB (18 – 20 GHz) typical
Main line power handling	0.1–2 GHz	100 W (50 dBm) average typical	100 W (50 dBm) average typical capability
		250 W (54 dBm) peak[3] typical	250 W (54 dBm) peak[3] typical
	2–18 GHz	50 W (47 dBm) average	
		50 W (47 dBm) average 250 W (54 dBm) peak[3]	250 W (54 dBm) peak[3]
	18–20 GHz	N/A	
		50 W (47 dBm) average typical N/A	250 W (54 dBm) peak[3] typical
Net weight		2.6 kg	0.8 kg
Dimensions (cm)		39.1 (L) x 13.34 (W) x 4.13 (H)	18.4 (L) x 10.5 (W) x 3.0 (H)

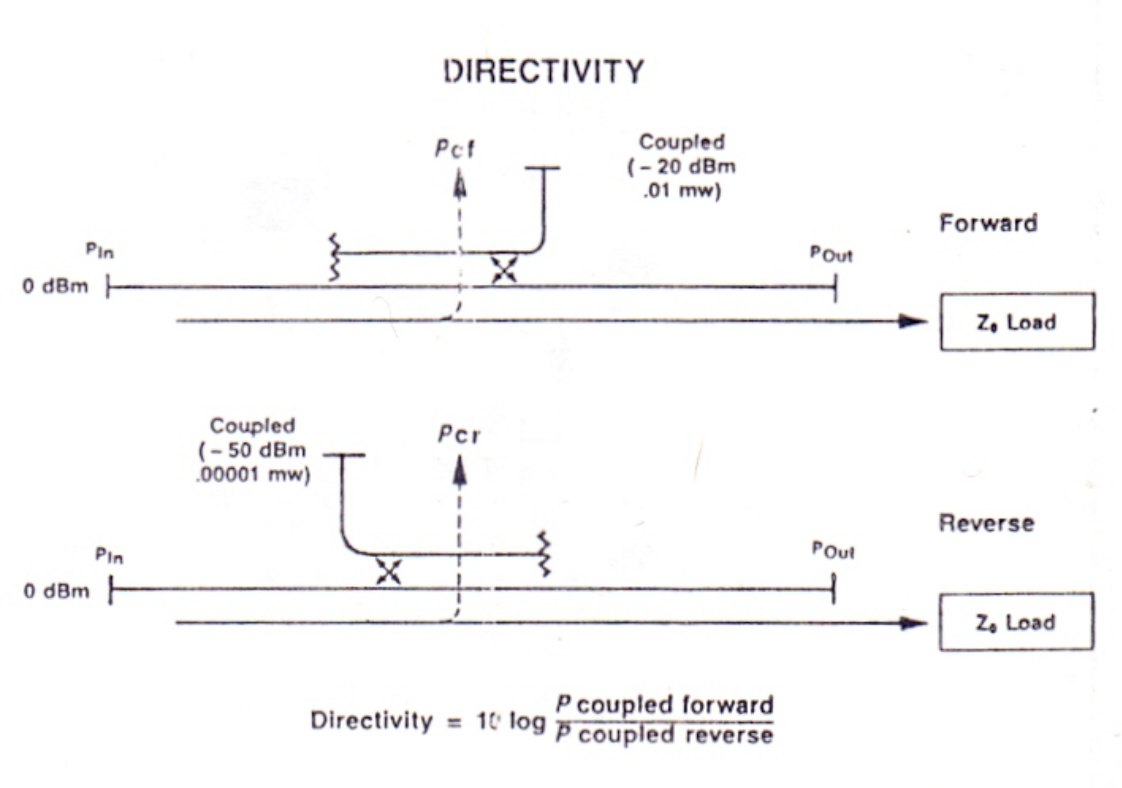
1. With test port shorted and not including source match ripple.
2. Typical relative tracking between 772D and 773D is <±0.7 dB.
3. Peak power duration of 10 µs
4. Nominal coupling = (Max. coupling + Min. coupling)/2

Conocimientos Previos

Acopladores direccionales





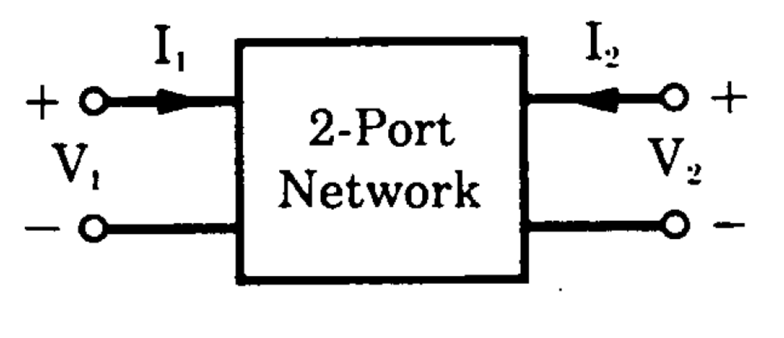


$$Directivity\ [dB] = Isolation[dB] - Coupling[dB]$$

$$Directivity\ [dB] = 50\ dB - 20dB = 30\ dB$$

Conocimientos Previos

Parámetros S (Scattering Parameters)



H-Parameters

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$

Y-Parameters

$$I_1 = y_{11} V_1 + y_{12} V_2$$
$$I_2 = y_{21} V_1 + y_{22} V_2$$

Z-Parameters

$$V_1 = z_{11} I_1 + z_{12} I_2$$
$$V_2 = z_{21} I_1 + z_{22} I_2$$

Problemas que presentan ….

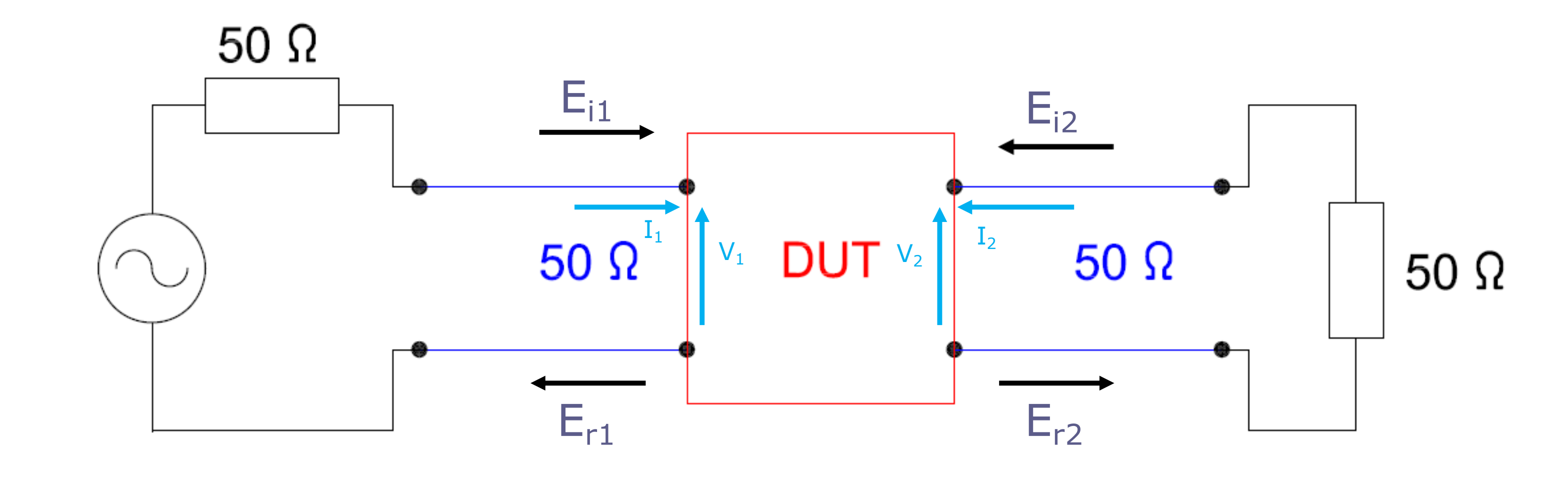
1) Es difícil medir la tensión total y la corriente total en el puerto de un dispositivo

2) Es difícil lograr un circuito abierto o un cortocircuito en un gran ancho de banda

3) Los dispositivos activos pueden presentar inestabilidades en condiciones de CA o CC

Conocimientos Previos

Parámetros S (Scattering Parameters)



H-Parameters

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$

$$V_1 = E_{i1} + E_{r1} \qquad V_2 = E_{i2} + E_{r2}$$

$$I_1 = \frac{E_{i1} - E_{r1}}{Z_0} \qquad I_2 = \frac{E_{i2} - E_{r2}}{Z_0}$$

$$E_{r1} = f_{11}(h)\, E_{i1} + f_{12}(h)\, E_{i2}$$
$$E_{r2} = f_{21}(h)\, E_{i1} + f_{22}(h)\, E_{i2}$$

dividiendo por $\sqrt{50}$

$$a_1 = \frac{E_{i1}}{\sqrt{Z_0}} \qquad a_2 = \frac{E_{i2}}{\sqrt{Z_0}}$$

$$b_1 = \frac{E_{r1}}{\sqrt{Z_0}} \qquad b_2 = \frac{E_{r2}}{\sqrt{Z_0}}$$

$$b_1 = S_{11}\, a_1 + S_{12}\, a_2$$
$$b_2 = S_{21}\, a_1 + S_{22}\, a_2$$

Conocimientos Previos

Parámetros S (Scattering Parameters)

Otro punto de vista….

$$E_{(d)} \cdot e^{j\cdot\omega\cdot t} = \frac{E_L + I_L \cdot Z_0}{2} \cdot e^{\alpha\cdot d} \cdot e^{j\cdot(\omega\cdot t+\beta\cdot d)} + \frac{E_L - I_L \cdot Z_0}{2} \cdot e^{-\alpha\cdot d} \cdot e^{j\cdot(\omega\cdot t-\beta\cdot d)}$$

$$a_1 = \frac{V_1 + I_1 Z_0}{2\sqrt{Z_0}} = \frac{\text{voltage wave incident on port 1}}{\sqrt{Z_0}} = \frac{V_{i1}}{\sqrt{Z_0}}$$

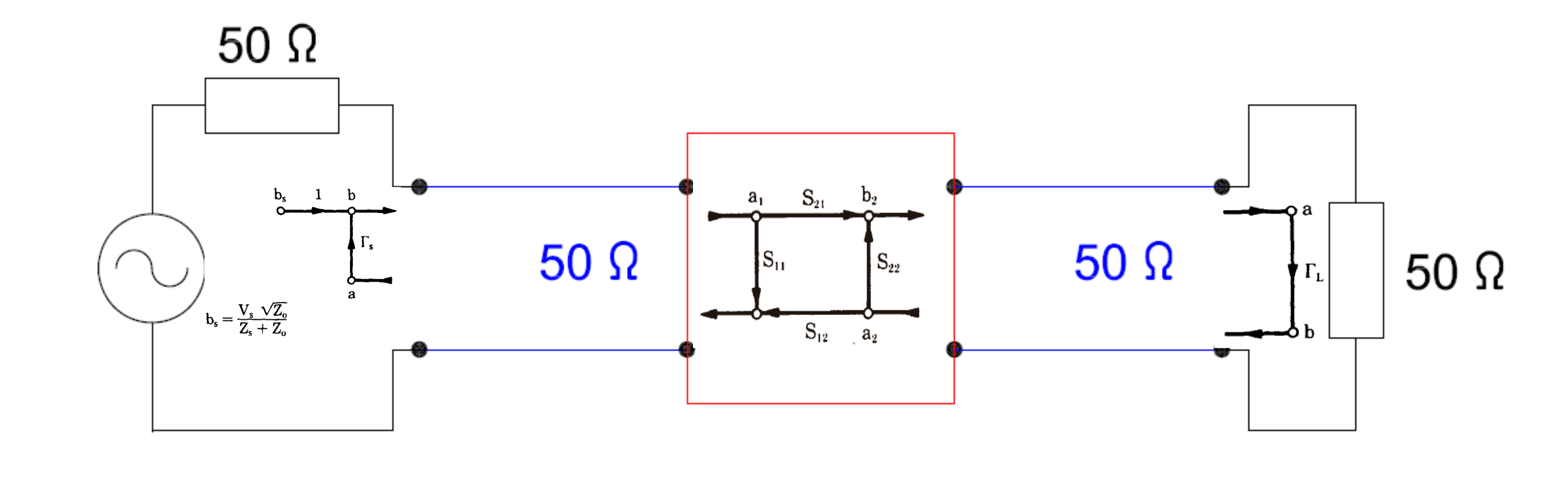
$$a_2 = \frac{V_2 + I_2 Z_0}{2\sqrt{Z_0}} = \frac{\text{voltage wave incident on port 2}}{\sqrt{Z_0}} = \frac{V_{i2}}{\sqrt{Z_0}}$$

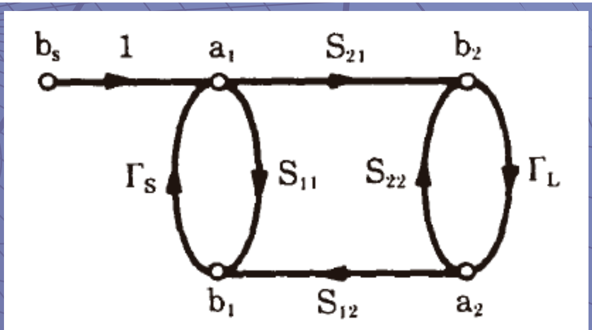
$$b_1 = \frac{V_1 - I_1 Z_0}{2\sqrt{Z_0}} = \frac{\text{voltage wave reflected from port 1}}{\sqrt{Z_0}} = \frac{V_{r1}}{\sqrt{Z_0}}$$

$$b_2 = \frac{V_2 - I_2 Z_0}{2\sqrt{Z_0}} = \frac{\text{voltage wave reflected from port 2}}{\sqrt{Z_0}} = \frac{V_{r2}}{\sqrt{Z_0}}$$

Conocimientos Previos

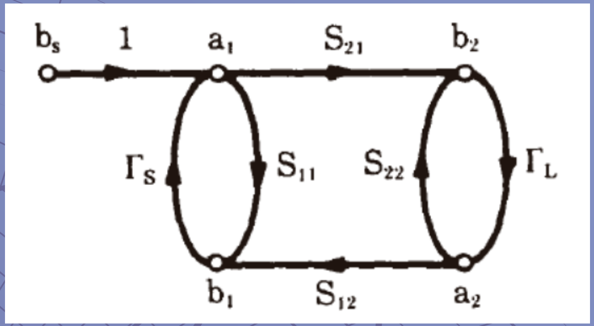
Parámetros S (Scattering Parameters)





Conocimientos Previos

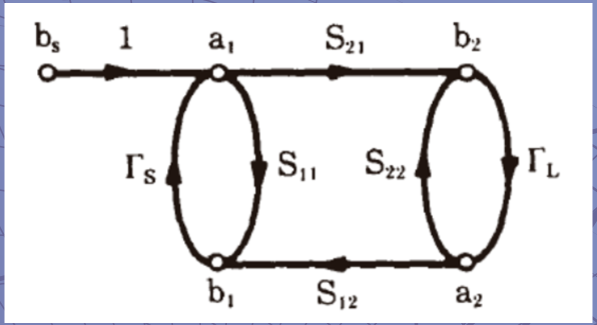
Parámetros S (Scattering Parameters)



Camino: paso entre 2 variables (puede haber mas de 1)
Lazo Orden 1: caminos que partiendo de una variable vuelven a la misma
Lazo Orden 2: Productos de los lazos de orden 1 tomados de a pares que no se tocan
*
*
*
Lazo de orden N: productos de los lazos de orden 1 tomados de a N que no se tocan

Conocimientos Previos

Parámetros S (Scattering Parameters)



$$T = \frac{\sum_{K=1}^{N} T_K \Delta_K}{\Delta}$$

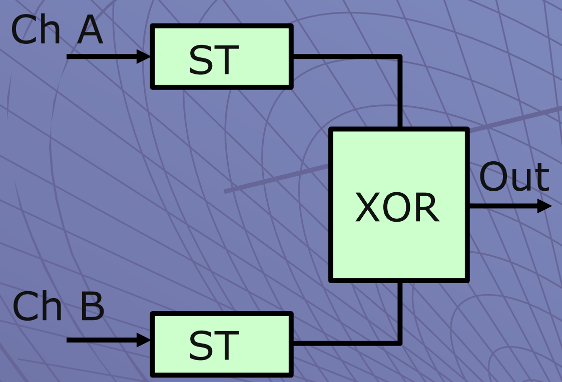
T_k = caminos entre las 2 variables que se quiere calcular la transferencia
Δ = 1 - Σ Lazos orden 1 + Σ Lazos orden 2 - Σ Lazos orden 3 + Σ….
Δ_k = Δ eliminado los términos que tengan lazos que toquen el camino T_k

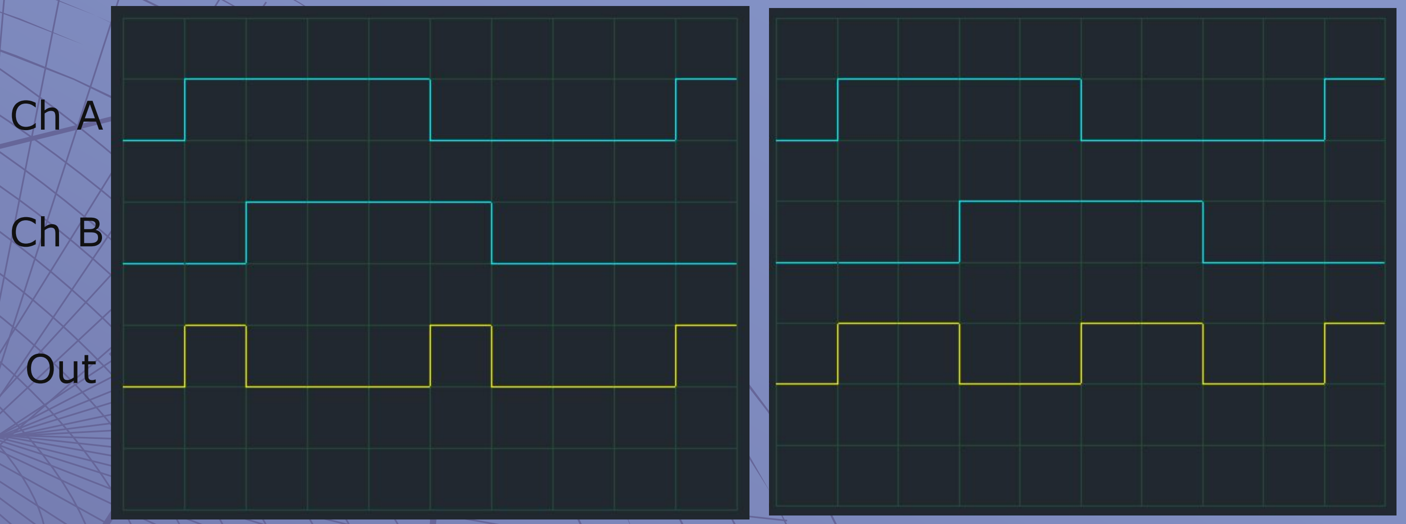
$$\Delta = 1 - (s_{11}\Gamma_S + s_{21}s_{12}\Gamma_L\Gamma_S + s_{22}\Gamma_L) + s_{11}s_{22}\Gamma_L\Gamma_S$$

$$\frac{b_2}{b_S} = \frac{s_{21}}{1 - s_{11}\Gamma_S - s_{22}\Gamma_L - s_{21}s_{12}\Gamma_L\Gamma_S + s_{11}\Gamma_S s_{22}\Gamma_L}$$

Conocimientos Previos

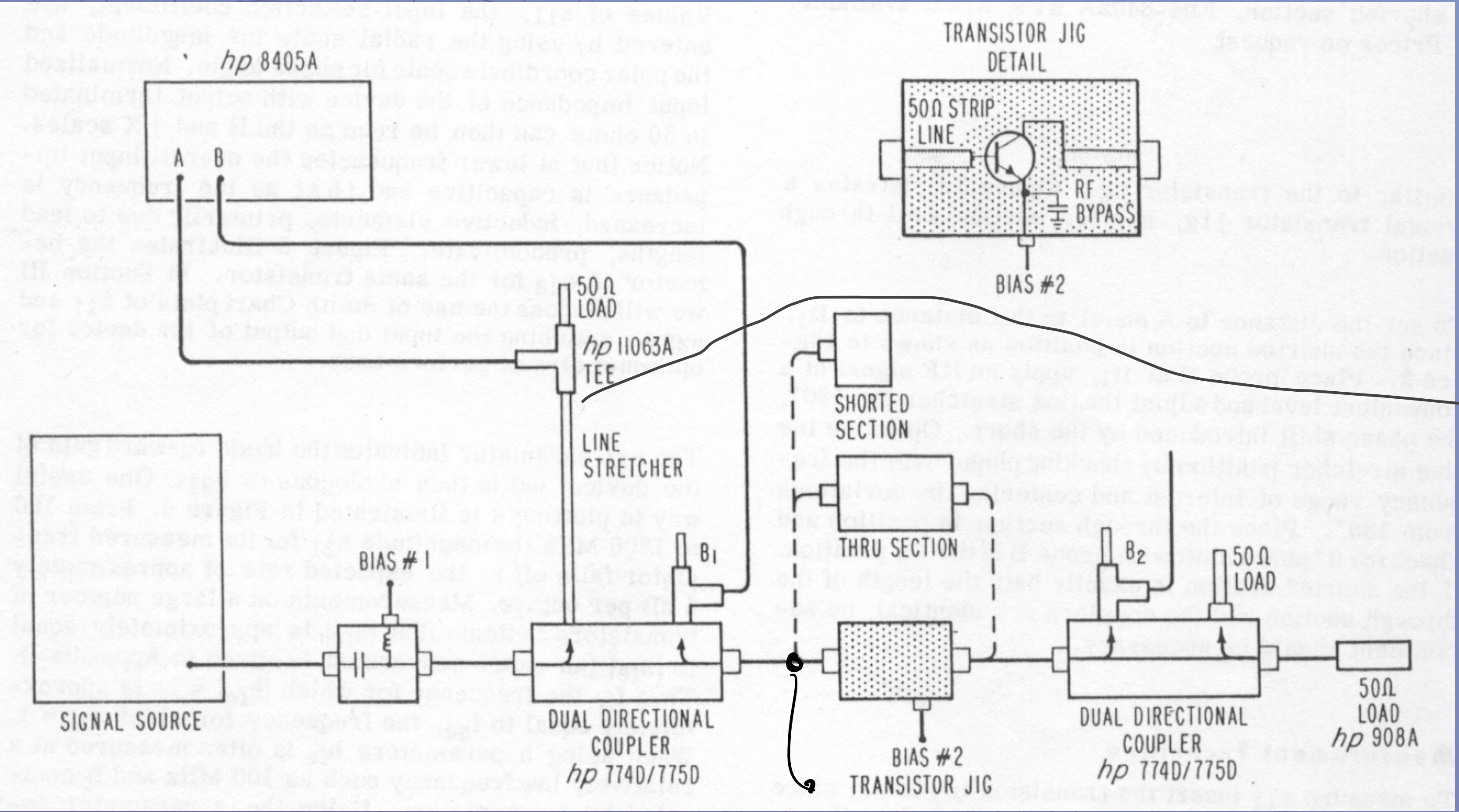
Como medir fase..





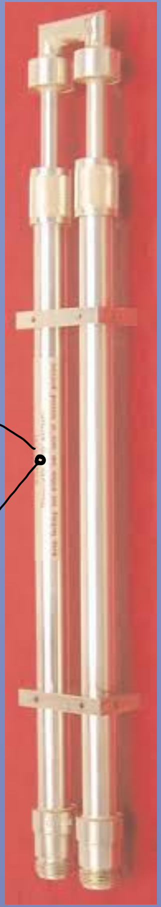
Conocimientos Previos

Como medir Parámetros S (Obsoleta)



medir E_i

medir E_r



modulo 1
fase 180° → para compensar medir Ei y Er en puntos diferentes

9/5

Conocimientos Previos

Analizador de Espectro y Tracking Generator

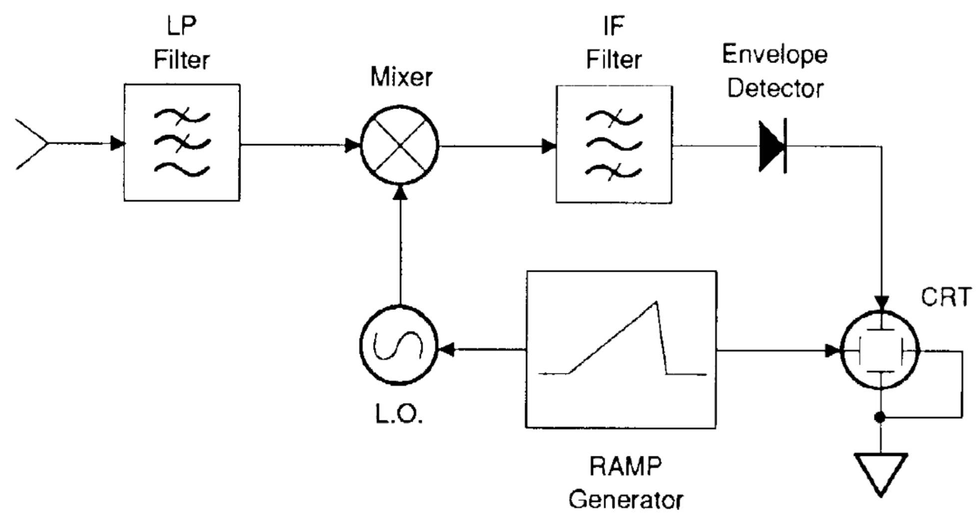


Figure 7. Superheterodyne spectrum analyzer

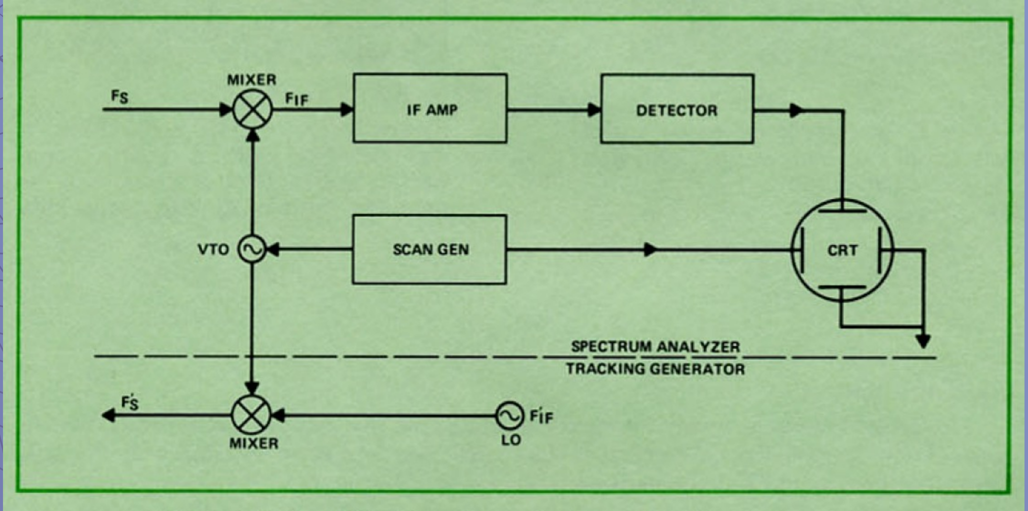
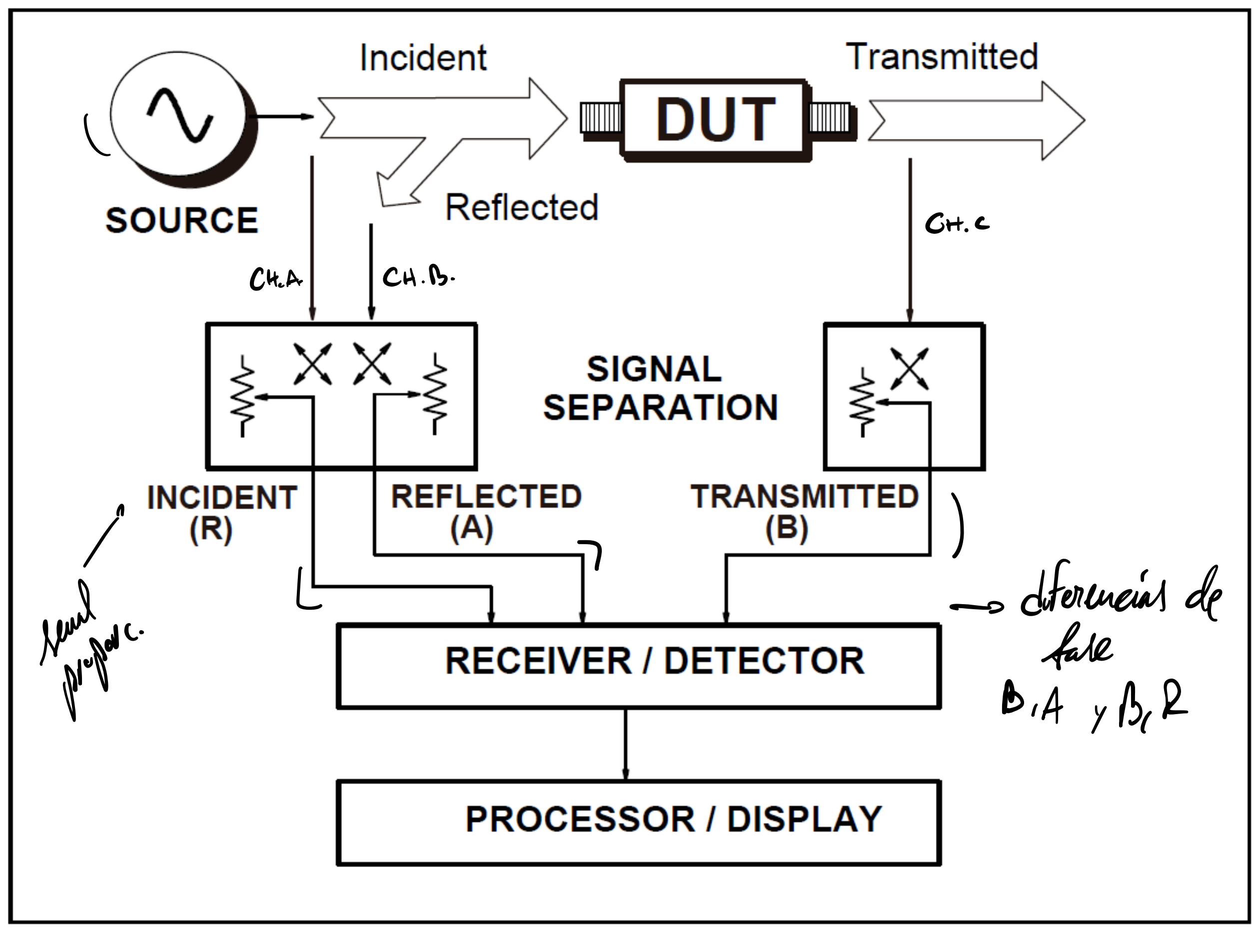


Figure 10. Simplified Spectrum Analyzer/Tracking Generator.

Analizador de Redes

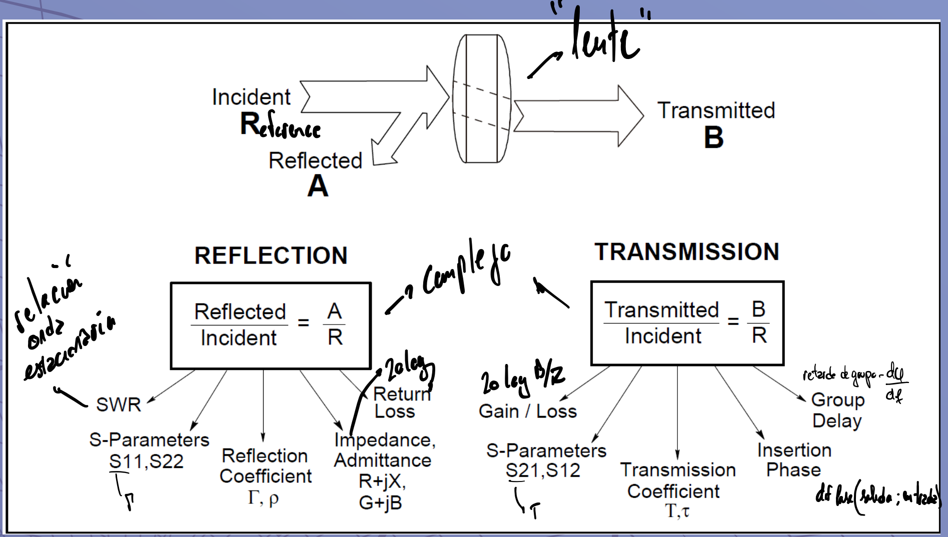
• Elimina errores sistemáticos



señal proporc.

→ diferencias de fase B,A y B,R

Analizador de Redes



Reflection Coefficient $\Gamma = \frac{V_{reflected}}{V_{incident}} = \rho\angle\Phi = \frac{Z_L - Z_O}{Z_L + Z_O}$

Return loss = $-20\log(\rho)$, $\rho = |\Gamma|$

Voltage Standing Wave Ratio

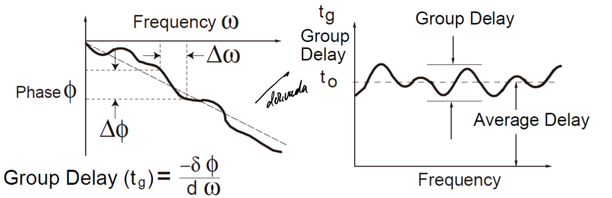
VSWR $= \frac{E_{max}}{E_{min}} = \frac{1+\rho}{1-\rho}$

No reflection ($Z_L = Z_O$)		Full reflection (Z_L = open, short)
0	ρ	1
∞ dB	**RL**	0 dB
1	**VSWR**	∞

Transmission Coefficient $= T = \frac{V_{Transmitted}}{V_{Incident}} = \tau\angle\phi$

Insertion Loss (dB) $= -20\,\text{Log}\left|\frac{V_{Trans}}{V_{Inc}}\right| = -20\log\tau$

Gain (dB) $= 20\,\text{Log}\left|\frac{V_{Trans}}{V_{Inc}}\right| = 20\log\tau$



Group Delay $(t_g) = \frac{-\delta\phi}{d\,\omega}$

$= \frac{-1}{360^o} * \frac{d\,\phi}{d\,f}$

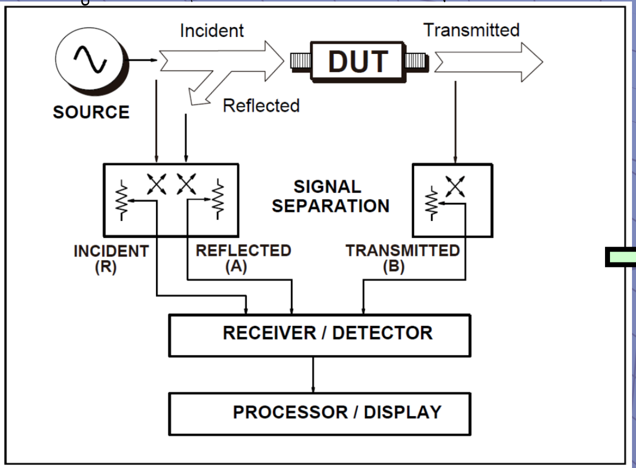
ϕ in radians
ω in radians/sec
ϕ in degrees
f in Hz ($\omega = 2\pi f$)

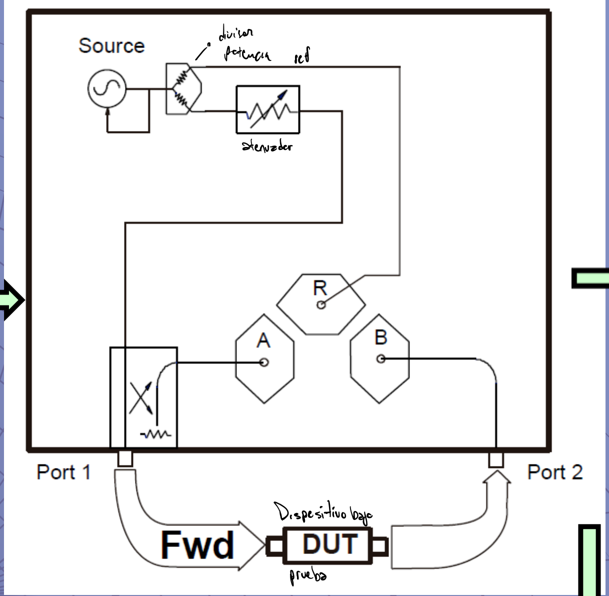
Deviation from constant group delay indicates distortion

Average delay indicates transit time

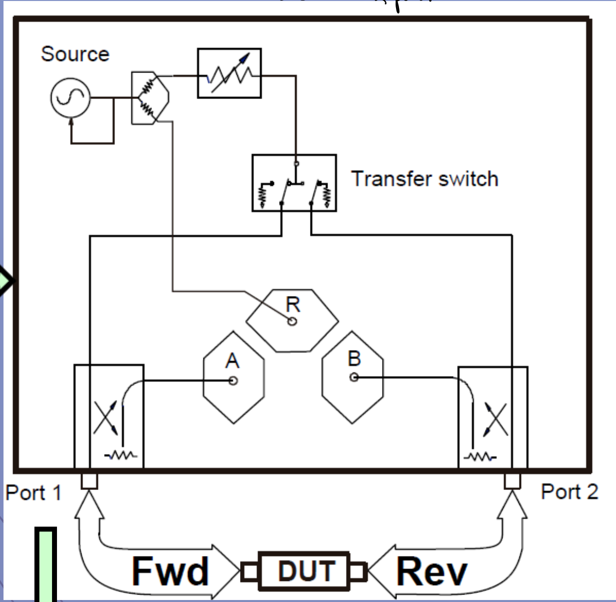
Analizador de Redes

Diagrama en bloques → Analizador de Redes de "1 puerto"

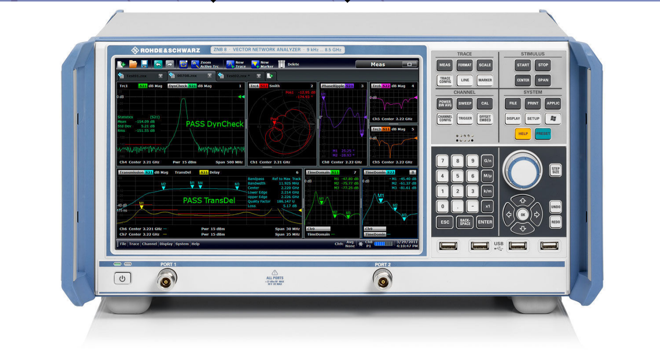




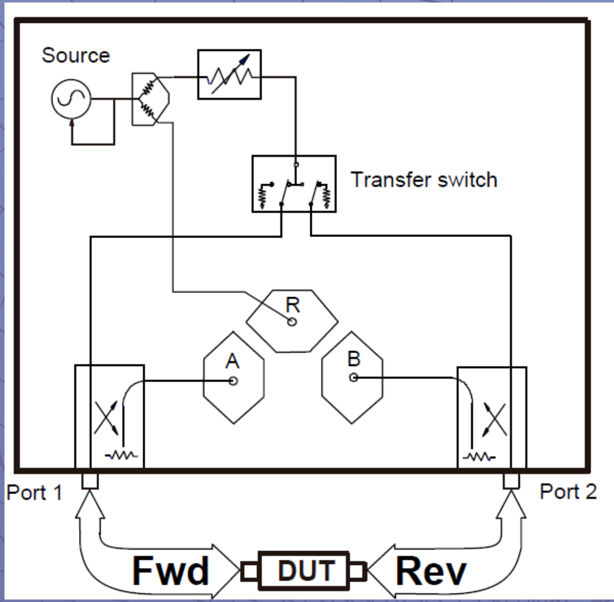
Analizador de 2 puertos

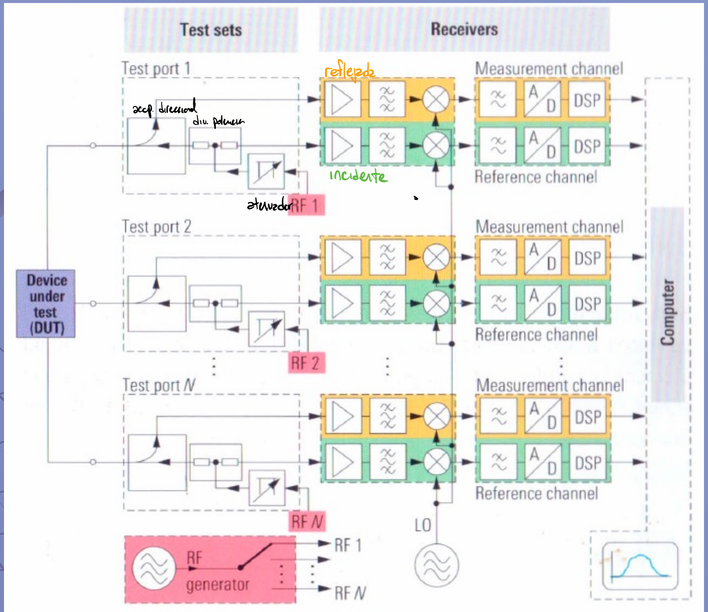


↳ para medir S22 o S21 no importa el DUT

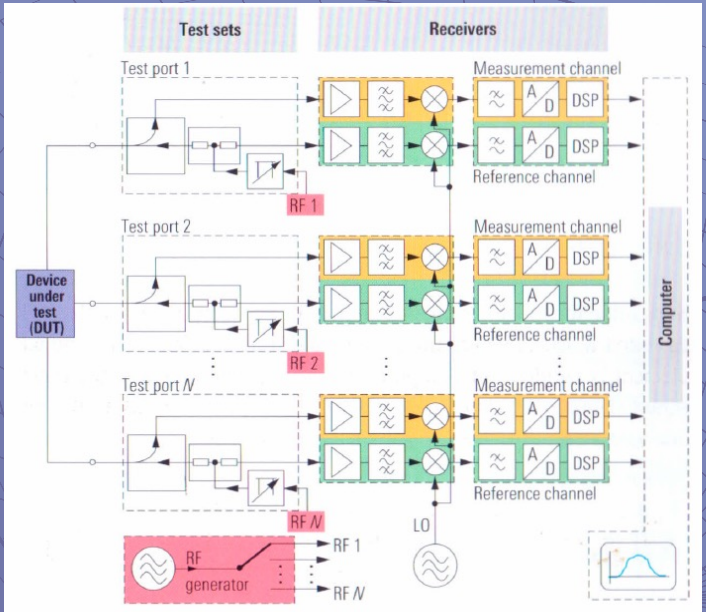


Analizador de Redes





Analizador de Redes



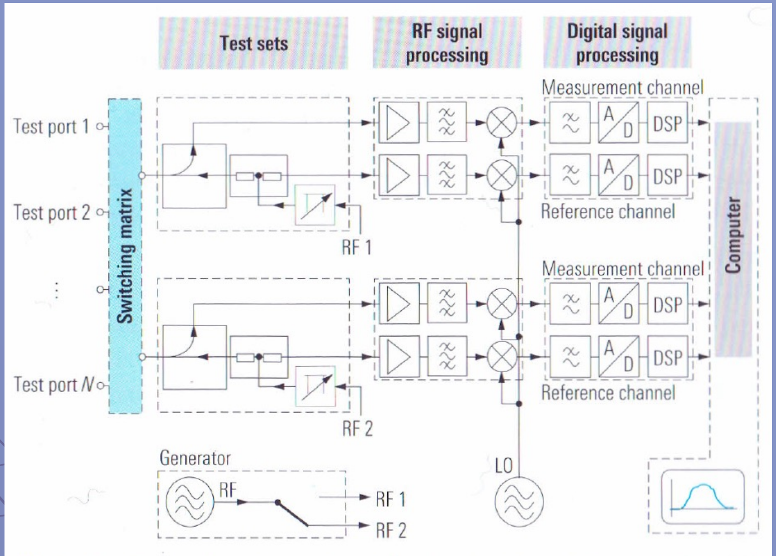
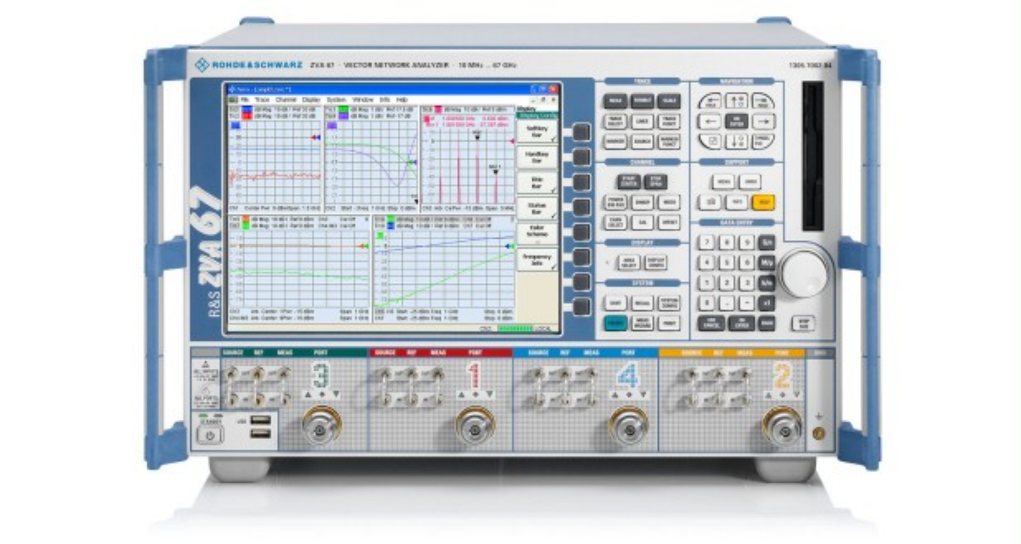


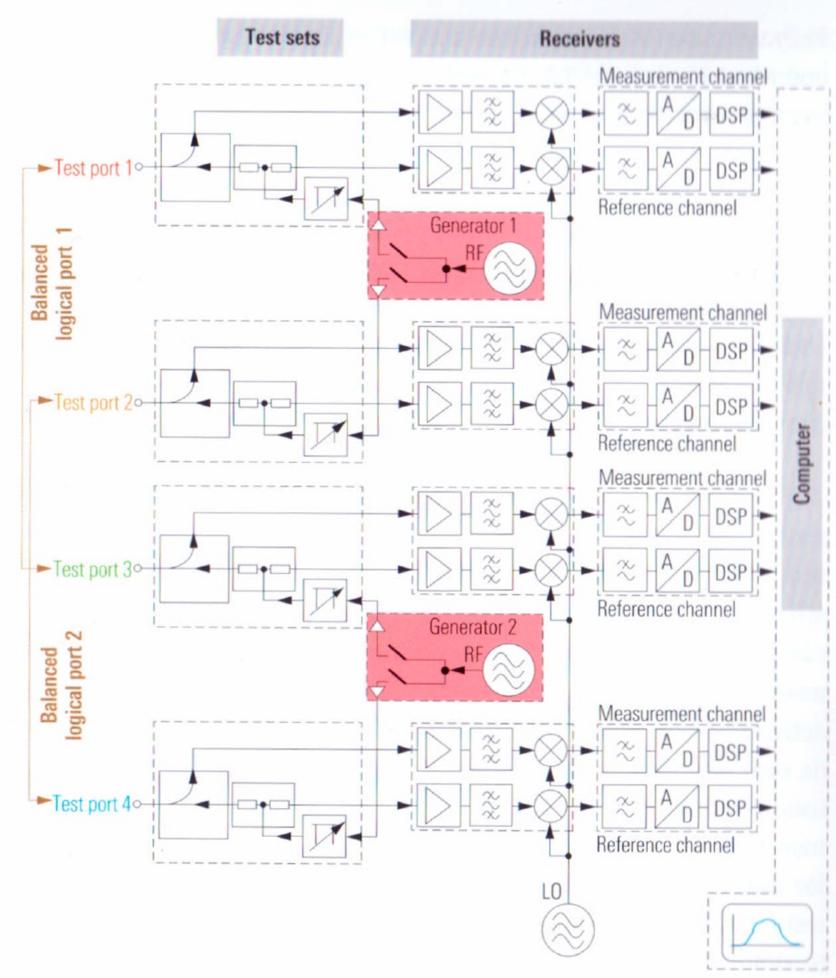
Fig. 2.10.2 *A network analyzer with an N-port switching matrix.*

Desventajas de ? respecto de

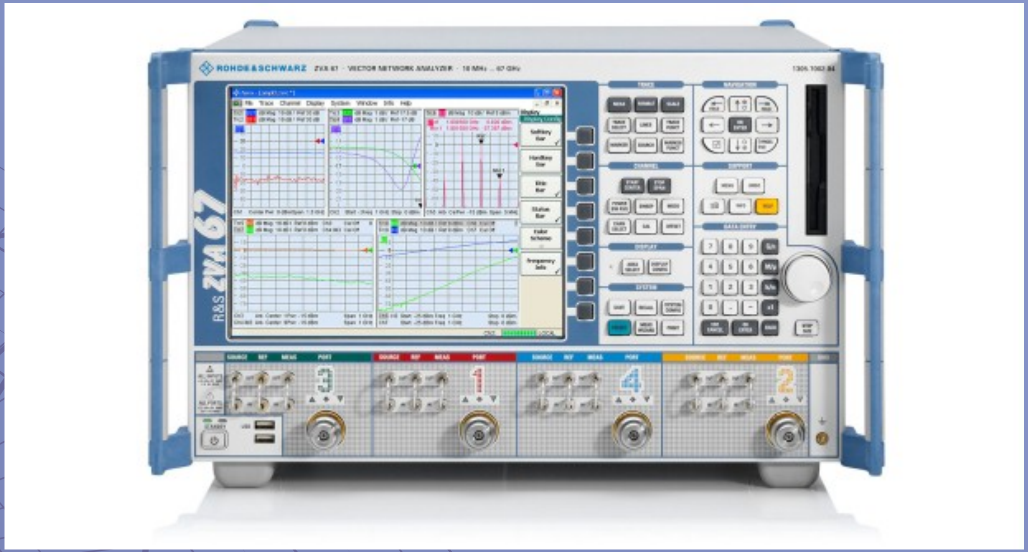
- No puede medir simultaneamente todas las b_i
- Si el switcheo es mecánico demora alta
- Si el switcheo es electrónico alta R.L. (-10 a -15 dB) y alta perdida de inserción (puede llegar a 16 dB a 8 Ghz dependiendo de la cantidad de puertos)
- Baja aislación (crosstalk) dentro de la matriz

Analizador de Redes





Analizador de Redes



divertido

más divertido

Key facts

•Linear and nonlinear amplifier and mixer measurements
•Noise figure measurements
•Pulse profile measurements with 12.5 ns resolution
•True differential measurements for reliable characterization of active devices with balanced ports
•High output power typ. > 18 dBm
•Wide dynamic range typ. > 140 dB
•High measurement speed < 3.5 µs per test point
•Wide IF bandwidth: 1/5/30 MHz
•Versatile calibration techniques: TOSM, TRL/LRL, TOM, TRM, TNA, UOSM
•Automatic calibration units
•Phase and group delay measurements on mixers with and without LO access
•Frequency range: 300 kHz to 8 GHz (R&S®ZVA8), 10 MHz to 24/40/50/67/110 GHz (R&S®ZVA24/40/50/67/110)

Analizador de Redes

The R&S®ZVT multiport network analyzers: Network analysis with up to eight test ports

Fig. A8.2 The R&S®ZVT8 multiport network analyzer.

The R&S®ZVT is the first network analyzer to combine up to eight test ports (8 GHz model R&S®ZVT8) and up to six test ports (20 GHz model R&S®ZVT20) in a single instrument. With its large number of test ports, it is the perfect instrument for investigating balanced networks, multipath filters and T/R modules. Its special hardware concept also allows it to generate a true-differential stimulus and to test double-converting devices quickly and flexibly with just one unit. The analyzer delivers outstanding performance in terms of stability, reproducibility, accuracy, sweep time, output power, receiver sensitivity and dynamic range. With its measurement capabilities (all functions of the R&S®ZVA are available for the R&S®ZVT as well), its flexibly configurable test set and varied interfaces, the R&S®ZVT is ideal for applications in complex test systems. 8-port and 6-port calibration units enable automatic calibration with a single keystroke.

Network analysis with millimeter-wave converters: Unprecedented convenience up to 500 GHz

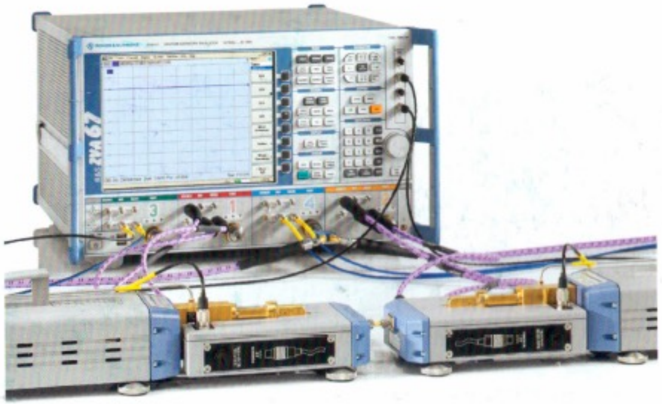
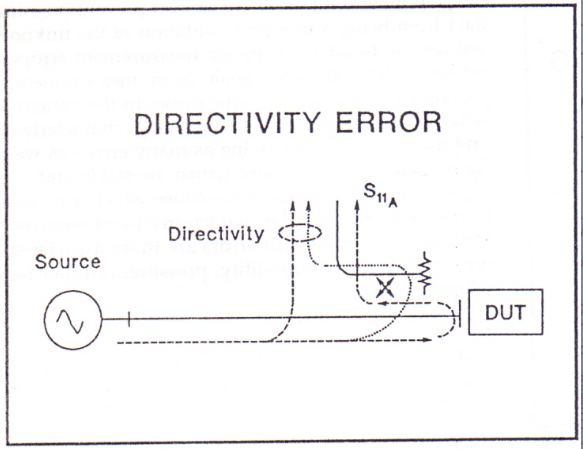


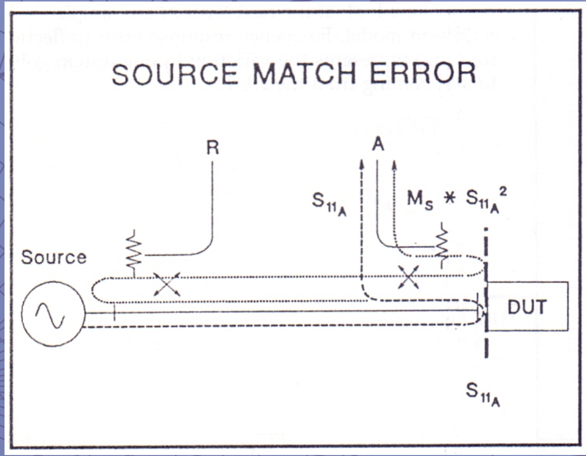
Fig. A8.3 The R&S®ZVA with millimeter-wave converters.

Rohde & Schwarz offers millimeter-wave converters for all common waveguide bands for use with the R&S®ZVA and R&S®ZVT families of network analyzers. The analyzers' and converters' hardware and software are perfectly matched to each other for the most accurate, highest dynamic range measurements and unparalleled ease of operation. The output power can be adjusted on all of the converters, even via the analyzer in some models, making it possible to perform the power sweeps required for compression measurements on amplifiers. Solutions up to 80 GHz or 110 GHz are available, providing complete coverage for the entire range from 10 MHz to the upper frequency limit.

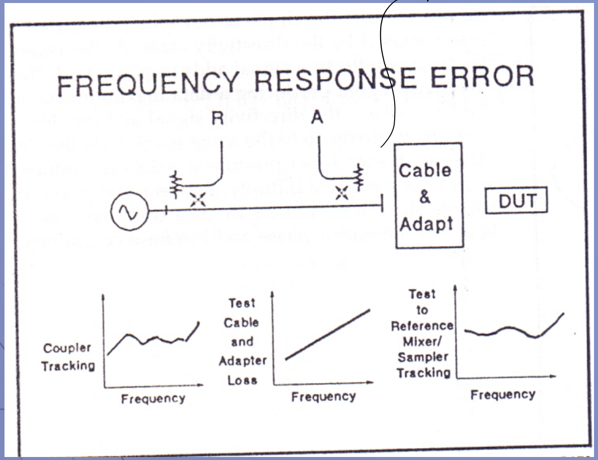
Año 2010 o antes

Analizador de Redes
Errores y porque calibrar…



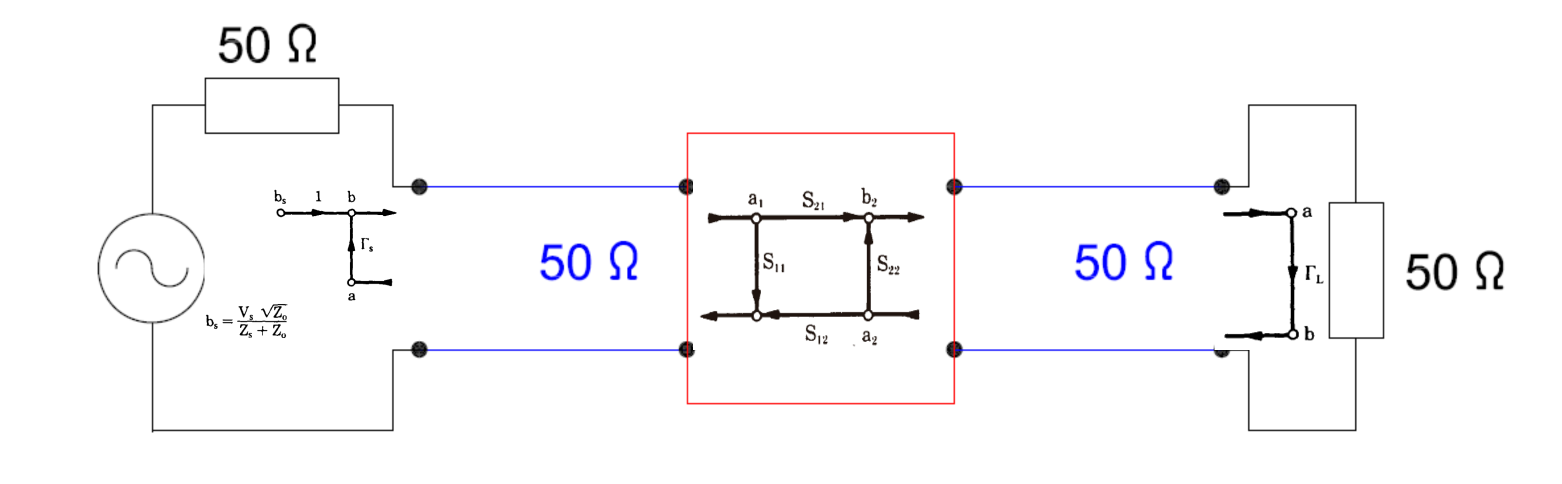


Si long. es muy grande puede medir en frecuencia errónea.

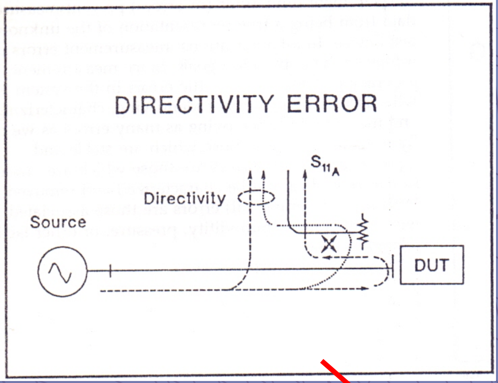


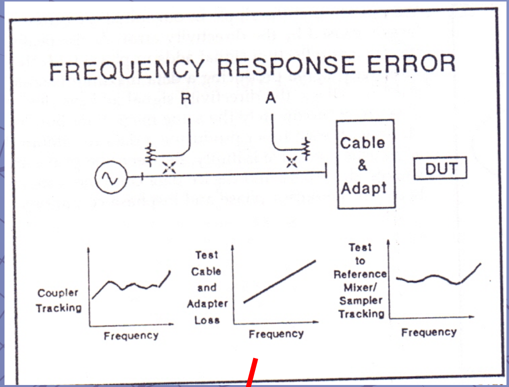
Errores del port donde esta entrando señal al DUT (S_{11} o S_{22})

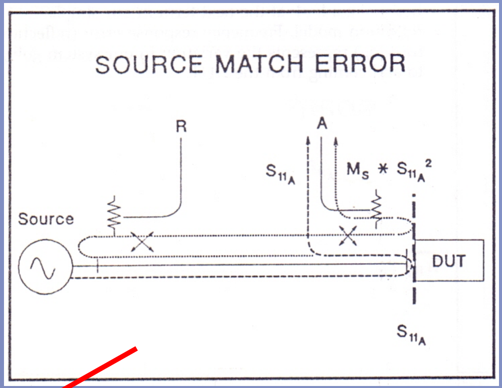
Analizador de Redes
Errores y porque calibrar…

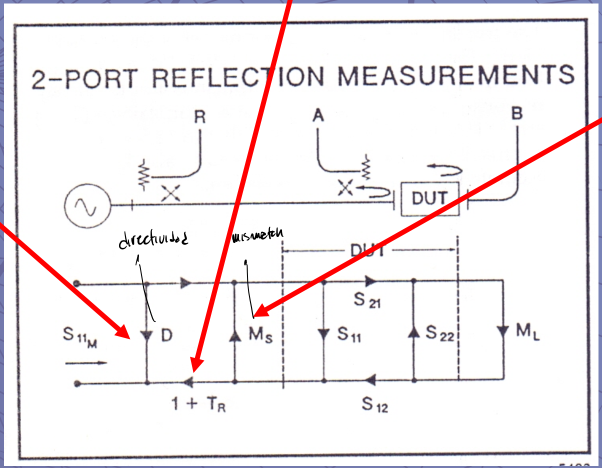


Analizador de Redes
Errores y porque calibrar…



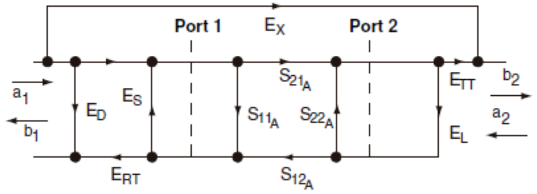




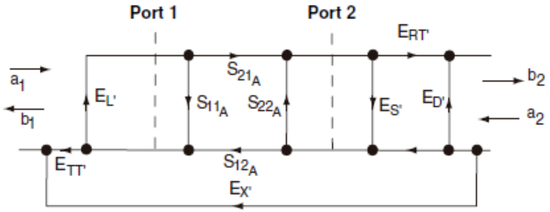


Analizador de Redes Errores y porque calibrar…

Forward model



Reverse model



E_D = Fwd Directivity
E_S = Fwd Source Match
E_{RT} = Fwd Reflection Tracking

E_L = Fwd Load Match
E_{TT} = Fwd Transmission Tracking
E_X = Fwd Isolation

$E_{D'}$ = Rev Directivity
$E_{S'}$ = Rev Source Match
$E_{RT'}$ = Rev Reflection Tracking

$E_{L'}$ = Rev Load Match
$E_{TT'}$ = Rev Transmission Tracking
$E_{X'}$ = Rev Isolation

- Notice that each actual S-parameter is a function of all four measured S-parameters
- Analyzer must make forward and reverse sweep to update any one S-parameter

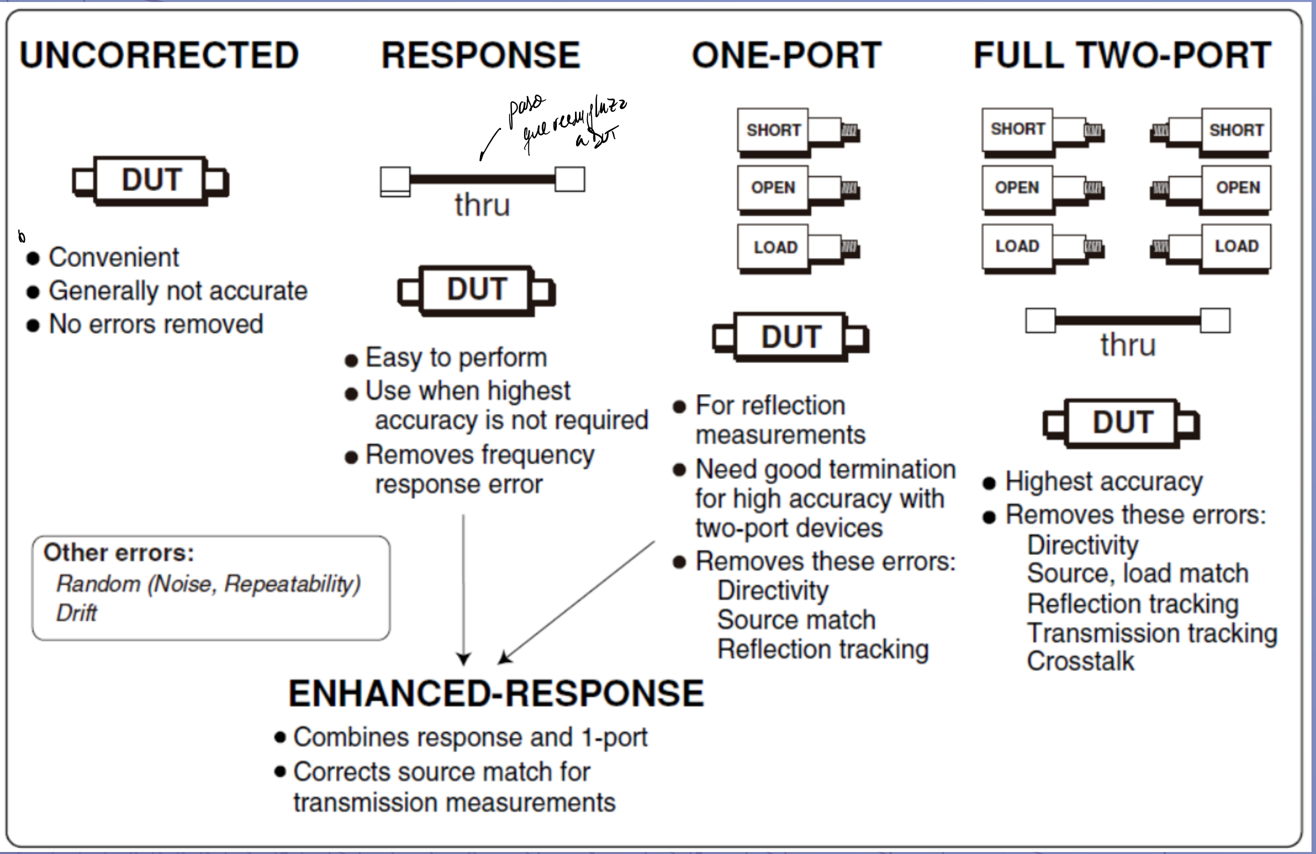
$$S_{11_a}=\frac{(\frac{S_{11m}-E_D}{E_{RT}})(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S')-E_L(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}{(1+\frac{S_{11m}-E_D}{E_{RT}}E_S)(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S')-E_L'E_L(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}$$

$$S_{21_a}=\frac{(\frac{S_{21m}-E_X}{E_{TT}})(1+\frac{S_{22m}-E_D'}{E_{RT}'}(E_S'-E_L))}{(1+\frac{S_{11m}-E_D}{E_{RT}}E_S)(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S')-E_L'E_L(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}$$

$$S_{12_a}=\frac{(\frac{S_{12m}-E_X'}{E_{TT}'})(1+\frac{S_{11m}-E_D}{E_{RT}}(E_S-E_L'))}{(1+\frac{S_{11m}-E_D}{E_{RT}}E_S)(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S')-E_L'E_L(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}$$

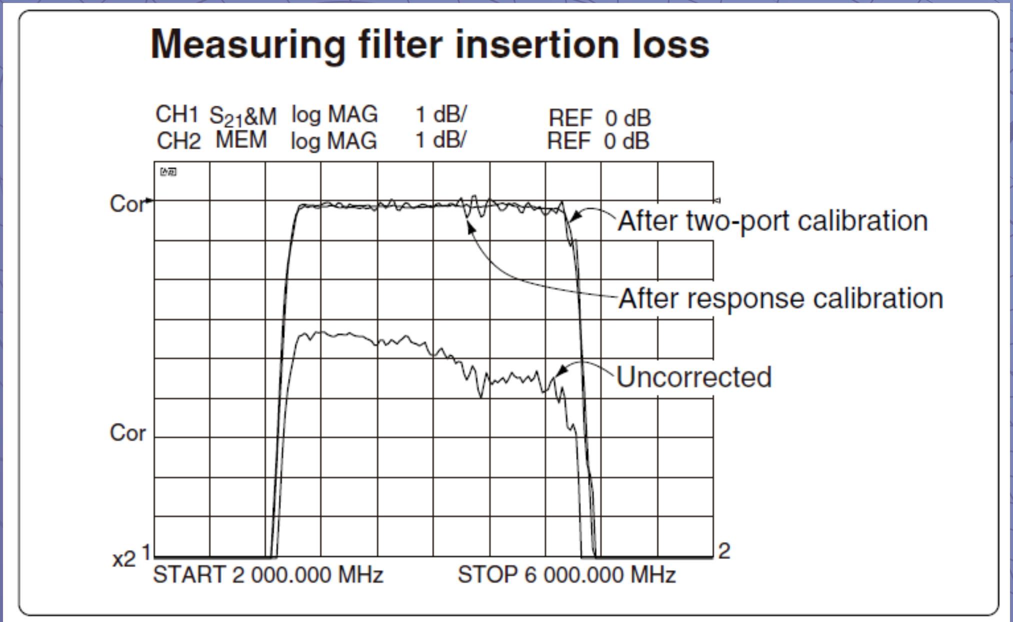
$$S_{22_a}=\frac{(\frac{S_{22m}-E_D'}{E_{RT}'})(1+\frac{S_{11m}-E_D}{E_{RT}}E_S)-E_L'(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}{(1+\frac{S_{11m}-E_D}{E_{RT}}E_S)(1+\frac{S_{22m}-E_D'}{E_{RT}'}E_S')-E_L'E_L(\frac{S_{21m}-E_X}{E_{TT}})(\frac{S_{12m}-E_X'}{E_{TT}'})}$$

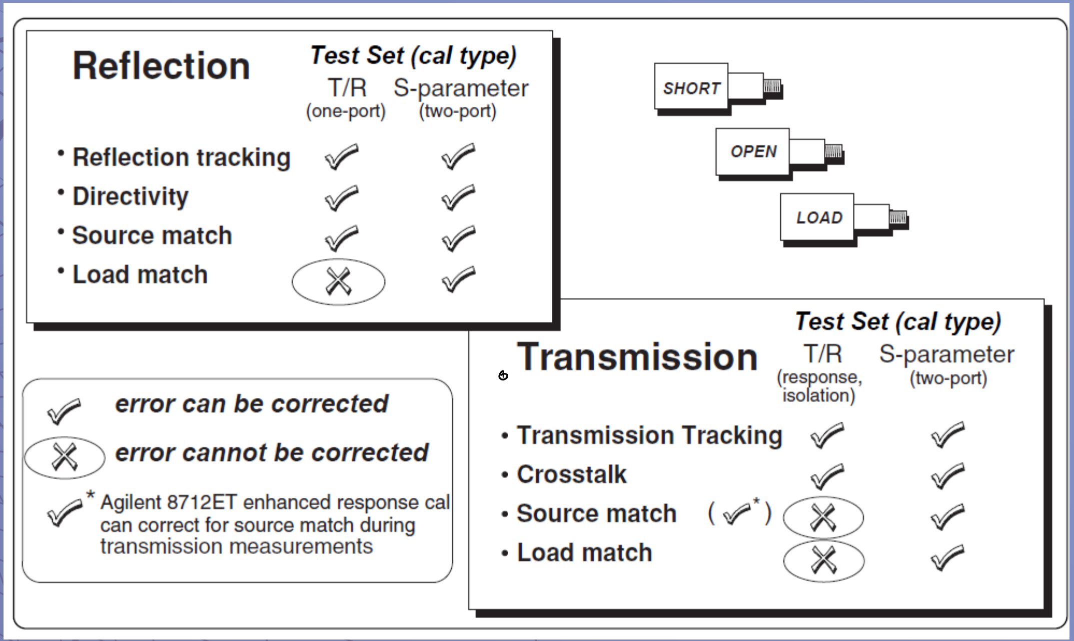
Analizador de Redes



No vale la pena corregir los errores sistemáticos restantes ya que quedan enmascarados por los errores aleatorios

Analizador de Redes
Errores y porque calibrar…





Analizador de Redes

kit de calibración

OSLT CALIBRATION KIT

Part number		BN 53 38 40		
Connector type		7-16 plug, 7-16 socket		
Impedance		50 Ω		
Frequency range		0 - 7.5 GHz		
Electrical data				
Open [1)]	Frequency range	0 - 3 GHz	3 - 6 GHz	6 - 7.5 GHz
	Phase error	≤ 0.5°	≤ 1°	≤ 1.5°
	Offset length socket		23.47 mm	
	Offset length plug		18.47 mm	
Short [1)]	Frequency range	0 - 3 GHz	3 - 6 GHz	6 - 7.5 GHz
	Phase error	≤ 0.5°	≤ 1°	≤ 1.5°
	Offset length socket		26.6 mm	
	Offset length plug		21.6 mm	
Load	Frequency range		0 - 7.5 GHz	
	Return loss		≥ 44 dB → no exac. 50Ω en todas las frec.	
	DC-resistance		50 Ω ±0.5	
Through	Frequency range	0 - 4 GHz	4 - 7.5 GHz	
	Return loss	≥ 40 dB	≥ 36 dB	
	Electrical length		39.16 mm	
Material and surface				
Inner conductor	CuBe age hardened	gold-plated		
	copper alloy	gold-plated		
Outer conductor	copper alloy	gold-plated		
Other metal parts	copper alloy	nickel-plated		

Analizador de Redes

kit de calibración

"lo caro" del kit

Calibration Data Format 1 (e.g. for Rhode & Schwarz VNAs)

The calibration data are individual for each single component. Do not use this data for components with other serial numbers.

OPEN							
	Offset Length [mm]	Offset Delay [ps]	Offset Loss [GΩ/s]	C0 [fF]	C1 [fF/GHz]	C2 [fF/GHz^2]	C3 [fF/GHz^3]
BN 806405 Plug Ser. No. S114205	18.468	61.6226	0.4	203	1.8	-0.12	0.07
BN 806505 Socket Ser. No. S114205	23.468	78.3062	0.4	204	0.7	0.22	0.05

SHORT							
	Offset Length [mm]	Offset Delay [ps]	Offset Loss [GΩ/s]	L0 [pH]	L1 [pH/GHz]	L2 [pH/GHz^2]	L3 [pH/GHz^3]
BN 806404 Plug Ser. No. S114205	21.6	72.0732	0.4	9	0	-0.25	0.03
BN 806504 Socket Ser. No. S114205	26.6	88.7568	0.4	10	0	-0.3	0.04

THROUGH			
	Electrical Length [mm]	Delay Time [ps]	Propagation Loss [GΩ/s]
BN 393307 Plug-plug Ser. No. S114205	39.22	130.82	0.4
BN 196404 Socket-socket Ser. No. S114205	39.28	131.03	0.4
BN Plug-socket Ser. No.			

Calibration Data Format 2 (e.g. for ANRITSU and AGILENT VNAs)

The calibration data are individual for each single component. Do not use this data for components with other serial numbers.

OPEN							
	Offset Length [mm]	Offset Delay [ps]	Offset Loss [GΩ/s]	C0 [$*10^{-15}$ F]	C1 [$*10^{-27}$ F/Hz]	C2 [$*10^{-36}$ F/Hz^2]	C3 [$*10^{-45}$ F/Hz^3]
BN 806405 Plug Ser. No. S114205	18.468	61.6226	0.4	203	1800	-120	70
BN 806505 Socket Ser. No. S114205	23.468	78.3062	0.4	204	700	220	50

SHORT							
	Offset Length [mm]	Offset Delay [ps]	Offset Loss [GΩ/s]	L0 [$*10^{-12}$ H]	L1 [$*10^{-24}$ H/Hz]	L2 [$*10^{-33}$ H/Hz^2]	L3 [$*10^{-42}$ H/Hz^3]
BN 806404 Plug Ser. No. S114205	21.6	72.0732	0.4	9	0	-250	30
BN 806504 Socket Ser. No. S114205	26.6	88.7568	0.4	10	0	-300	40

THROUGH			
	Electrical Length [mm]	Delay Time [ps]	Propagation Loss [GΩ/s]
BN 393307 Plug-plug Ser. No. S114205	39.22	130.82	0.4
BN 196404 Socket-socket Ser. No. S114205	39.28	131.03	0.4
BN Plug-socket Ser. No.			

Analizador de Redes

(Tipos de analizadores)

Escalares:

No es posible medir fase.

No pueden medir todos los parámetros.

Vectoriales:

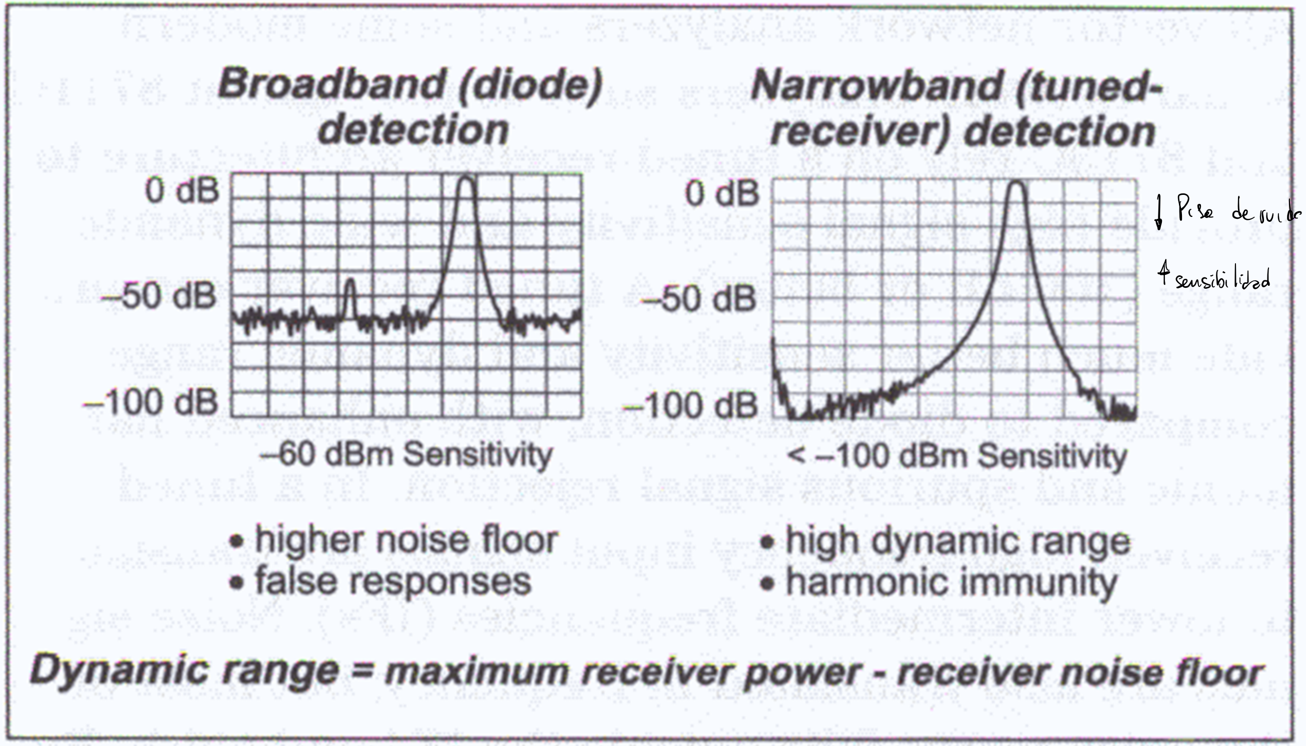
Permiten medir amplitud y fase

¿Cuál es el motivo de que existan los escalares?

¡¡¡COSTO!!!

Analizador de Redes

(Tipos de analizadores)



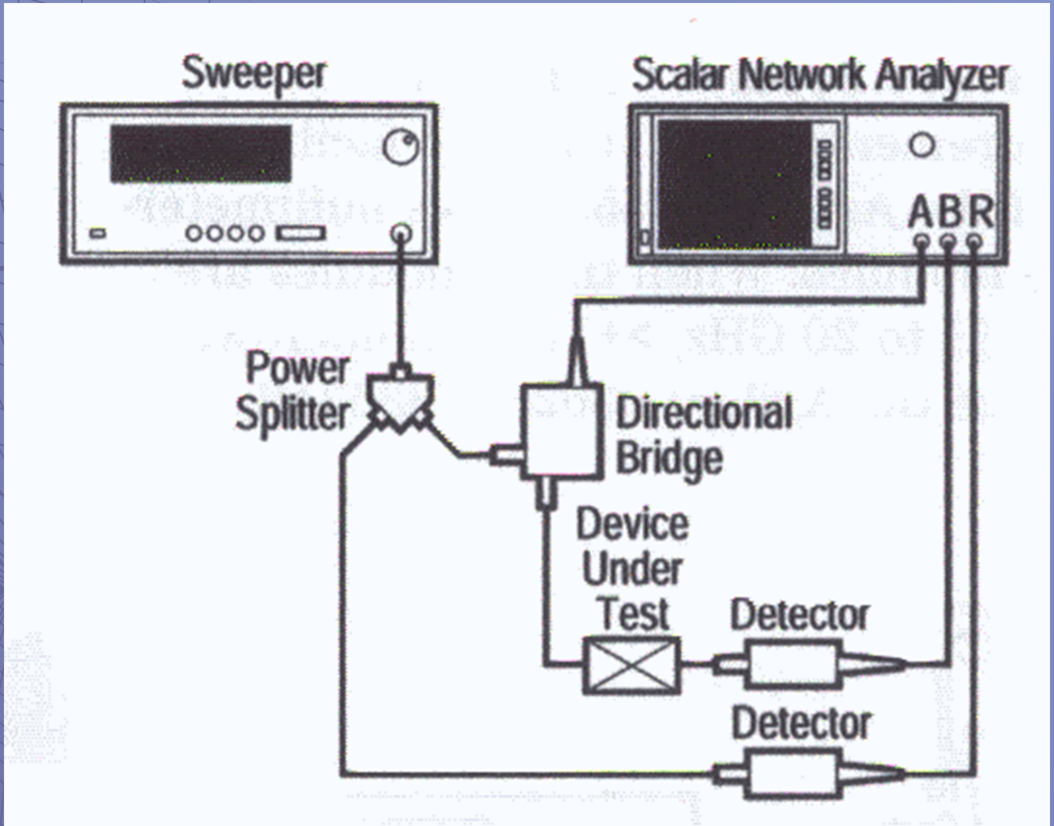
↓ Piso de ruido

↑ sensibilidad

Figure 7. Comparison of Receiver Techniques

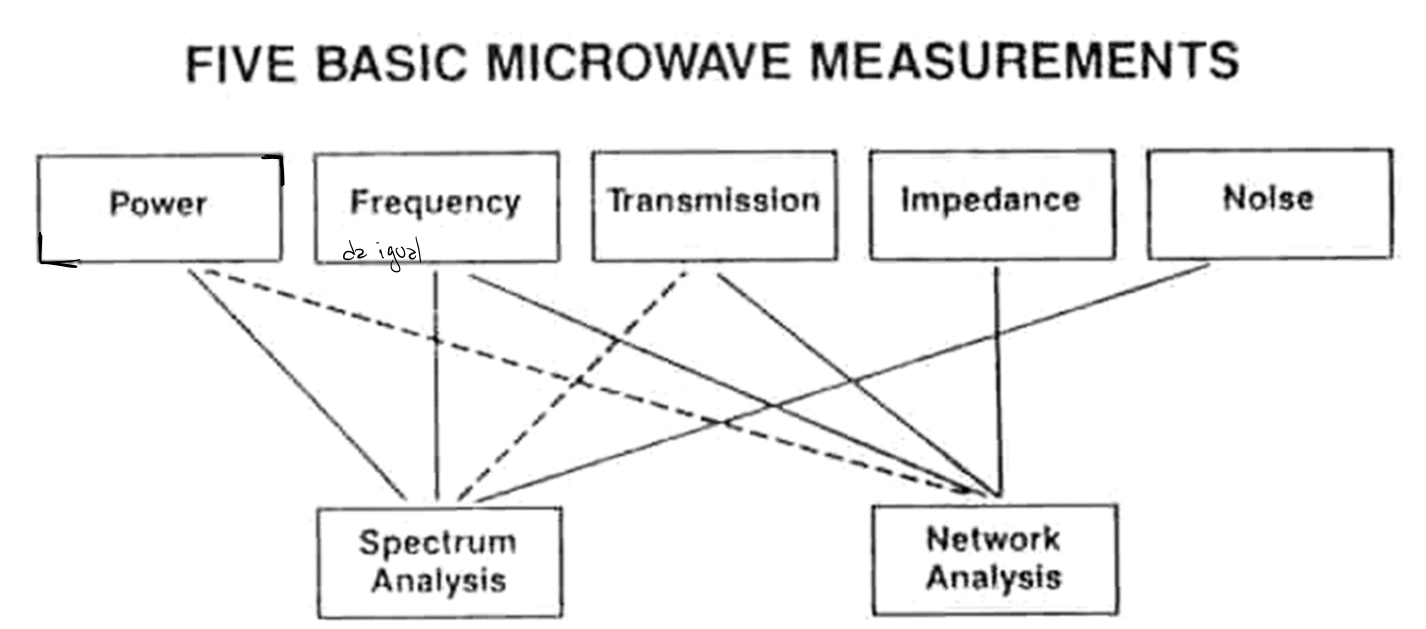
Analizador de Redes

(escalar)



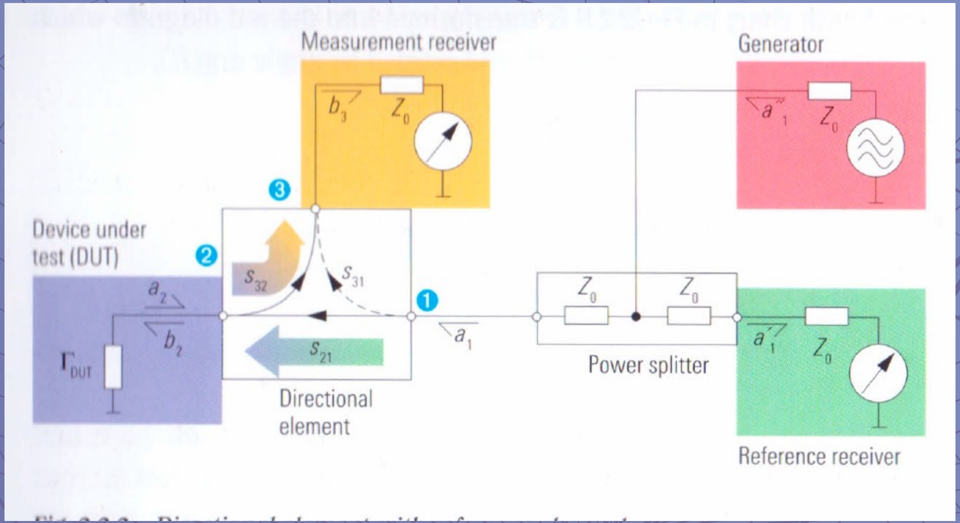
Analizador de Redes

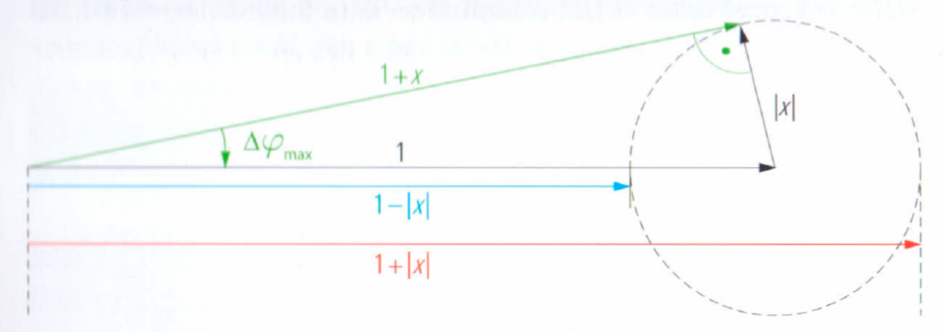
(qué mide un Analizador de Espectro y que mide un Analizador de Redes)



Analizador de Redes

(importancia de la directividad de los acopladores direccionales)





$\Gamma_{DUT} = \frac{a_2}{b_2}$ ⇒ $\Gamma_M = \frac{b_3}{a'_1}$ ⇒ $\Gamma_M = s_{21} * s_{32} * \Gamma_{DUT}$ (solo si S_{31} es nulo)

$D = \frac{s_{31}}{s_{32} * s_{21}}$ ⇒ $\Gamma_M = s_{21} * s_{32} * (\Gamma_{DUT} + D) = s_{21} * s_{32} * \Gamma_{DUT} * (1 + x)$ ⇒ $x = \frac{D}{\Gamma_{DUT}}$

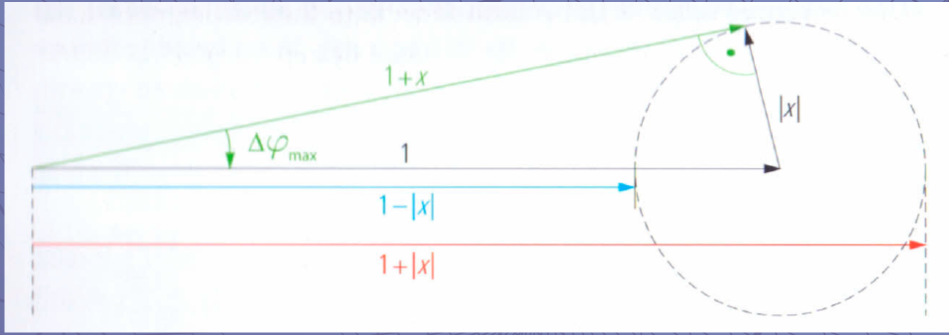
$|x|_{[dB]} = |D|_{[dB]} - |\Gamma_{DUT}|_{[dB]}$

Analizador de Redes

(importancia de la directividad de los acopladores direccionales)

Suponiendo acoplador direccional sin perdidas (S32 y S21 iguales a 1)

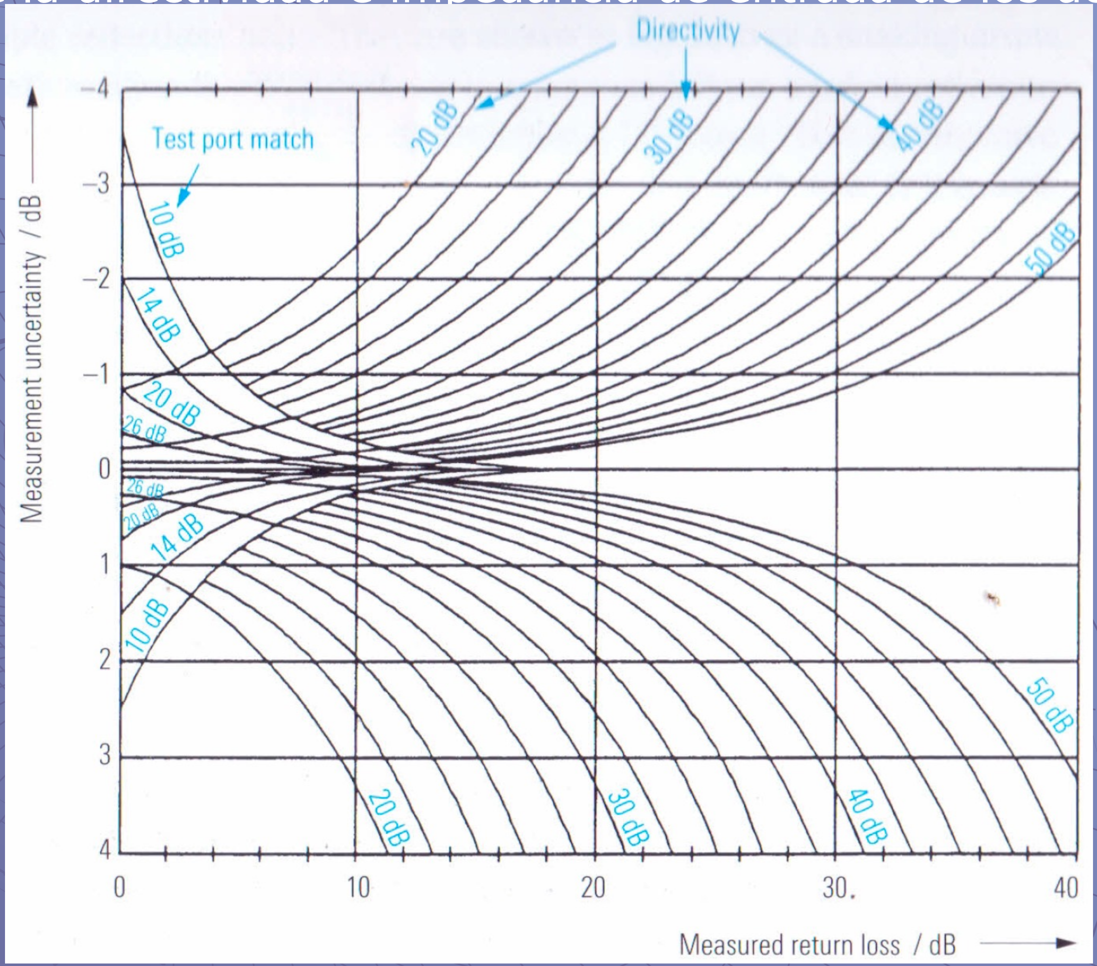
$$\Gamma_M = \Gamma_{DUT} * (1 + x)$$



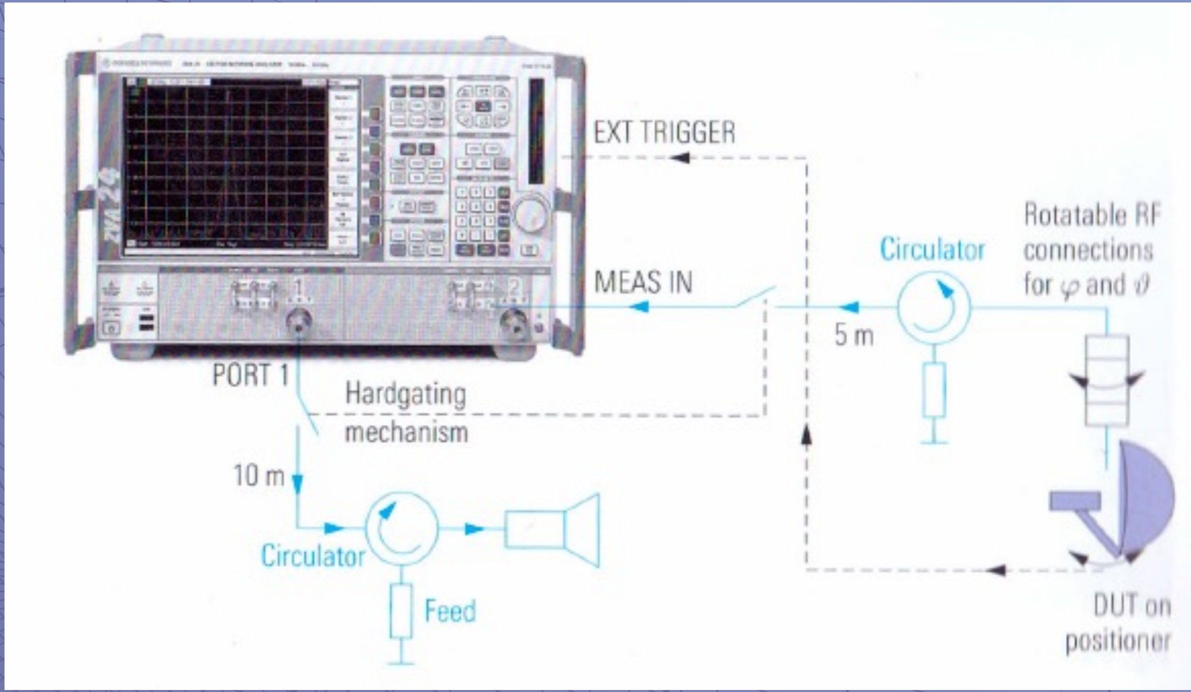
$\|x\|$	$1+\|x\|$	$1-\|x\|$	$\Delta\varphi_{max}$
0 dB	6.02 dB	−∞	90.00°
−1 dB	5.53 dB	−19.27 dB	63.03°
−2 dB	5.08 dB	−13.74 dB	52.59°
−3 dB	4.65 dB	−10.69 dB	45.07°
−4 dB	4.25 dB	−8.66 dB	39.12°
−5 dB	3.88 dB	−7.18 dB	34.22°
−6 dB	3.53 dB	−6.04 dB	30.08°
−7 dB	3.21 dB	−5.14 dB	26.53°
−8 dB	2.91 dB	−4.41 dB	23.46°
−9 dB	2.64 dB	−3.81 dB	20.78°
−10 dB	2.39 dB	−3.30 dB	18.43°
−11 dB	2.16 dB	−2.88 dB	16.37°
−12 dB	1.95 dB	−2.51 dB	14.55°
−13 dB	1.75 dB	−2.20 dB	12.94°
−14 dB	1.58 dB	−1.93 dB	11.51°
−15 dB	1.42 dB	−1.70 dB	10.24°
−16 dB	1.28 dB	−1.50 dB	9.12°
−17 dB	1.15 dB	−1.32 dB	8.12°
−18 dB	1.03 dB	−1.17 dB	7.23°
−19 dB	0.92 dB	−1.03 dB	6.44°
−20 dB	0.83 dB	−0.92 dB	5.74°
−21 dB	0.74 dB	−0.81 dB	5.11°
−22 dB	0.66 dB	−0.72 dB	4.56°
−23 dB	0.59 dB	−0.64 dB	4.06°
−24 dB	0.53 dB	−0.57 dB	3.62°
−25 dB	0.48 dB	−0.50 dB	3.22°
−30 dB	0.27 dB	−0.28 dB	1.81°
−35 dB	0.15 dB	−0.16 dB	1.02°
−40 dB	0.09 dB	−0.09 dB	0.57°
−45 dB	0.05 dB	−0.05 dB	0.32°
−50 dB	0.03 dB	−0.03 dB	0.18°

Analizador de Redes

(importancia de la directividad e impedancia de entrada de los acopladores direccionales)



Analizador de Redes



Analizador de Redes

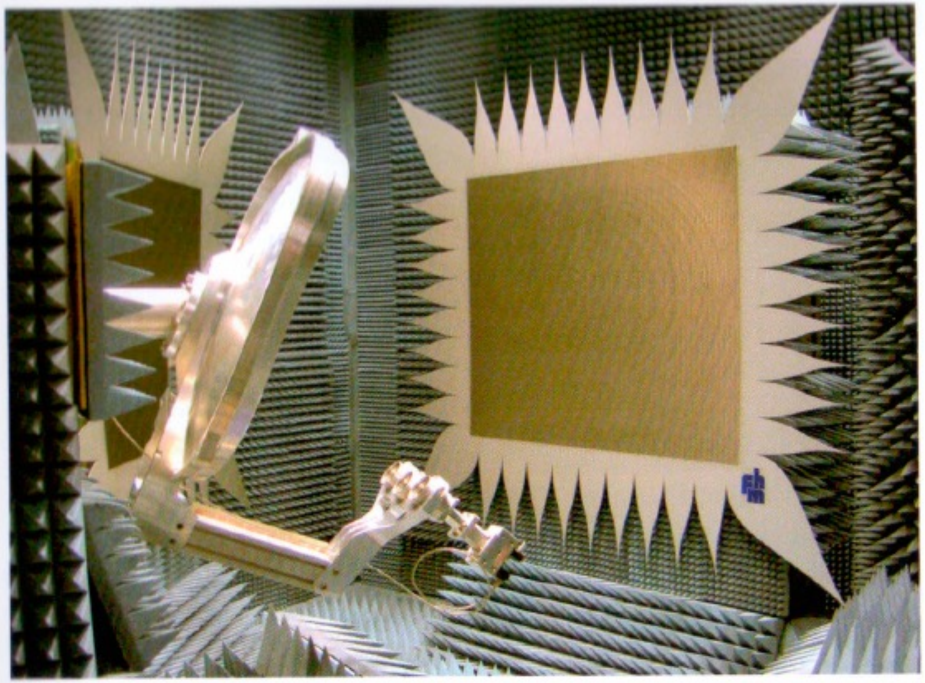
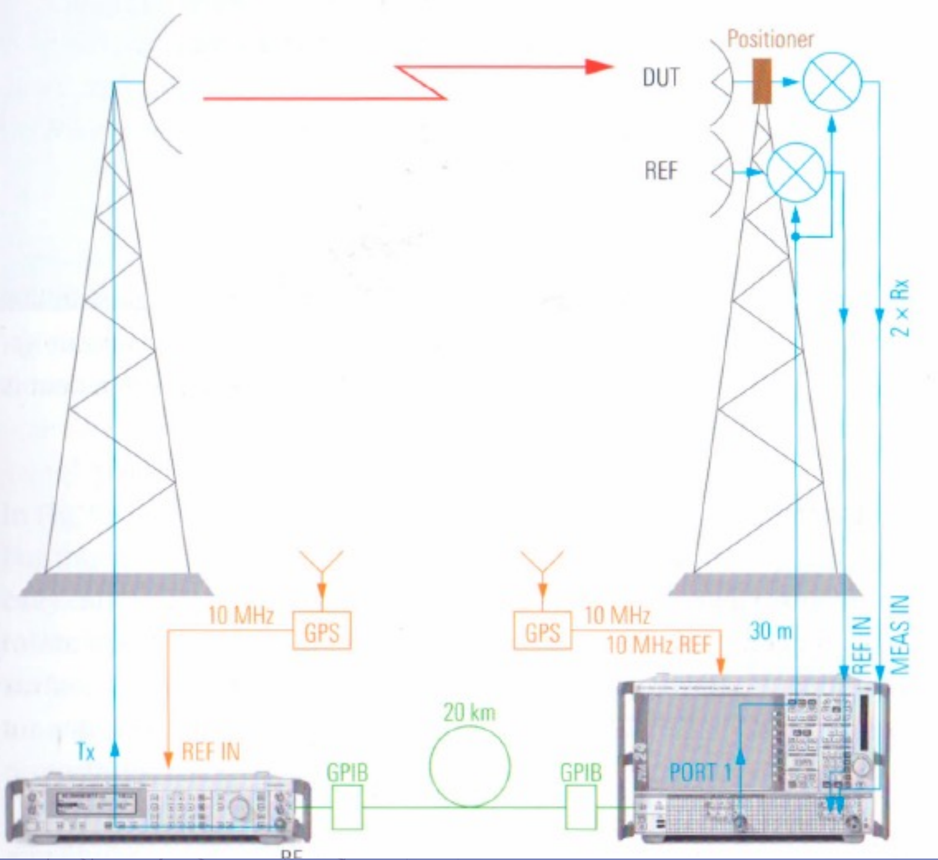
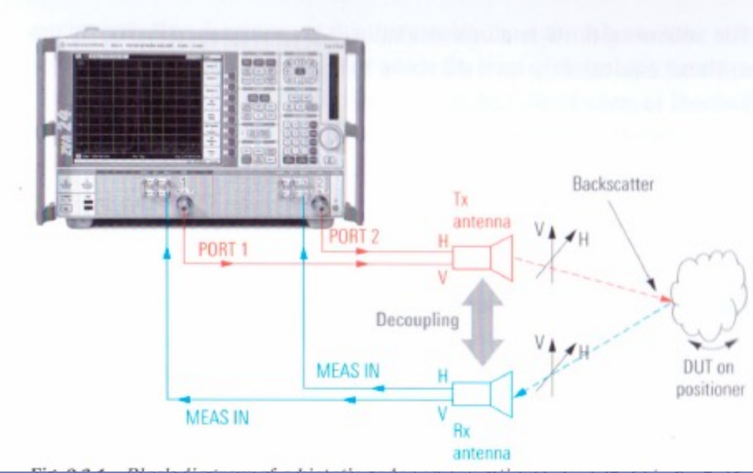
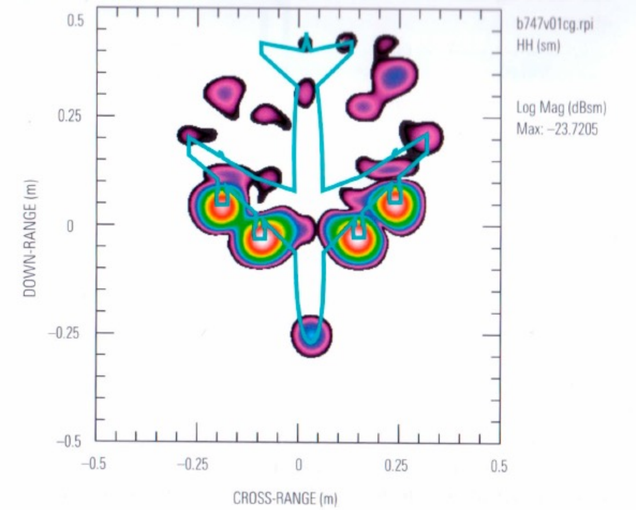


Fig. 9.1.5 Test of a multi beam / shaped beam reflector antenna in the 12 GHz range (compensated compact test range: Munich University of Applied Sciences; antenna: KATHREIN).



Analizador de Redes





Object	Radar cross section in m²	Radar cross section in dBsm
Automobile	100	20
Commercial airline	40	16
Fighter plane	2 to 6	3 to 7.78
Adult person	1	0
Bird	0.01	−20
Insect	0.00001	−50
Advanced stealth fighter	0.000001	−60

Table 9.3.1 Typical radar cross sections, taken from [1EZ52].

modelo de radiación de
un 747

Analizador de Redes